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RESISTANCE-REPELLENT RETROVIRAL PROTEASE INHIBITORS

5 The present invention relates to retroviral protease inhibitors and, more particularly, relates to novel compounds, compositions and methods for inhibiting retroviral proteases. This invention, in particular, relates to resistance-repellent HIV protease inhibitors, compositions, and uses thereof for treating HIV infections, particularly infections caused by one or more species of drug resistant HIV strains.

BACKGROUND OF THE INVENTION

10 Acquired immune deficiency syndrome (AIDS) is a fatal disease, reported cases of which have increased dramatically within the past several years. Estimates of reported cases in the very near future also continue to rise dramatically. Consequently, there is a great need to develop drugs and vaccines to combat AIDS.

15 The AIDS virus was first identified in 1983. It has been known by several names and acronyms. It is the third known T-lymphocyte virus (HTLV-III), and it has the capacity to replicate within cells of the immune system, causing profound cell destruction. The AIDS virus is a retrovirus, a virus that uses reverse transcriptase during replication. This particular retrovirus is also known as lymphadenopathy-associated virus (LAV), AIDS-related virus (ARV) and, most recently, as human immunodeficiency virus (HIV). Two
20 distinct families of HIV have been described to date, namely HIV-1 and HIV-2. The acronym HIV is used hereinafter to refer to HIV viruses generically.

Specifically, HIV is known to exert a profound cytopathic effect on CD4+ helper/inducer T-cells, thereby severely compromising the immune system. HIV infection also results in neurological deterioration and, ultimately, in the death of the infected individual.

5 The field of viral chemotherapeutics has developed in response to the need for agents effective against retroviruses, in particular HIV. Theoretically, there are many ways in which an agent can exhibit anti-retroviral activity. The HIV genome encodes several viral-specific enzymes, such as reverse transcriptase (RT), integrase and protease (PR); viral-specific regulatory proteins, such as
10 tat, rev, nef and vif; and, numerous viral-specific structural proteins, and numerous viral-specific structural proteins, such as capsid, nucleocapsid, matrix, and envelope proteins. Many of these proteins are essential for viral replication. Accordingly, viral replication theoretically could be inhibited through inhibition of any one or all of the proteins involved in viral
15 replication. In practice, however, only inhibitors of RT and PR are currently available for antiviral therapy.

Nucleoside analogues (NRTIs), such as 3'-azido-2',3'-dideoxythymidine (AZT), 2',3'-dideoxycytidine (ddC), and 2',3'-dideoxyinosine (ddI) are known to inhibit HIV RT. There also exist non-nucleoside inhibitors (NNRTIs)
20 specific for HIV-1 RT, such as Nevirapine, and Efavirenz.

Retroviral PR inhibitors (PIs) have also been identified as a class of anti-retroviral agents. The retroviral PR processes polyprotein precursors into viral structural proteins and replicative enzymes. This processing is essential for the assembly and maturation of fully infectious virions. Accordingly, the design of
25 PIs that selectively inhibit PR has been an important therapeutic goal in the treatment of HIV infections and AIDS. Strategies used in the design of HIV PIs include substrate-based, peptidomimetic, transition state-based, and

structure-based drug design (Wlodawer & Erickson, *Ann. Rev. Biochem.*, 62, 543-585 (1992)).

Numerous classes of potent peptidic inhibitors of PR have been designed using the natural cleavage site of the precursor polyproteins as a starting point. These inhibitors typically are peptide substrate analogs in which the scissile P1-P1' amide bond has been replaced by a non-hydrolyzable isostere with tetrahedral geometry (Moore et al., *Perspect. Drug Dis. Design*, 1, 85 (1993); Tomasselli et al., *Int. J. Chem. Biotechnology*, 6 (1991); Huff, *J. Med. Chem.*, 34, 2305 (1991); Norbeck et al., *Ann. Reports Med. Chem.*, 26, 141 (1991); Meek, *J. Enzyme Inhibition*, 6, 65 (1992)).

The design of HIV-1 PIs based on the transition-state mimetic concept has led to the generation of a variety of peptide derivatives highly active against viral replication *in vitro* (Erickson et al., *Science*, 249, 527-533 (1990); Kramer et al., *Science*, 231, 1580-1584 (1986); McQuade et al., *Science*, 247, 454-456 (1990); Meek et al., *Nature (London)*, 343, 90-92 (1990); Roberts et al., *Science*, 248, 358-361 (1990)). These active agents contain a non-hydrolyzable, dipeptide isostere such as hydroxyethylene (McQuade et al., *supra*; Meek et al., *Nature (London)*, 343, 90-92 (1990); Vacca et al., *J. Med. Chem.*, 34, 1225-1228 (1991)) or hydroxyethylamine (Rich et al., *J. Med. Chem.*, 33, 1285-1288 (1990); Roberts et al., *Science*, 248, 358-361 (1990)) as an active moiety which mimics the putative transition state of the aspartic protease-catalyzed reaction.

Two-fold (C₂) symmetric inhibitors of HIV protease represent another class of potent HIV PIs which were created by Erickson et al. on the basis of the three-dimensional symmetry of the enzyme active site (Erickson et al., *supra*).

Typically, the usefulness of currently available HIV PIs in the treatment of AIDS has been limited by relatively short plasma half-life, poor oral

bioavailability, and the technical difficulty of scale-up synthesis (Meek et al. (1992), *supra*). Although these inhibitors are effective in preventing the retroviral PR from functioning, the inhibitors suffer from some distinct disadvantages. Generally, peptidomimetics make poor drugs due to their potential adverse pharmacological properties, i.e., poor oral absorption, poor stability and rapid metabolism (Plattner et al., Drug Discovery Technologies, Clark et al., eds., Ellish Horwood, Chichester, England (1990)). Furthermore, since the active site of the PR is hindered, i.e., has reduced accessibility as compared to the remainder of the PR, the ability of the inhibitors to access and bind in the active site of the PR is impaired. Those inhibitors that do bind are generally poorly water-soluble, causing distinct problems for formulation and drug delivery.

There are currently six FDA-approved PIs for clinical use – Saquinavir, Ritonavir, Indinavir, Nelfinavir, Amprenavir and Lopinavir. When used alone or in combination with RT inhibitors, PIs dramatically suppress viral replication in HIV-infected individuals. Accordingly, PIs have become “first-line” antiviral agents for the control of HIV-1 (HIV) infections and are widely used in most highly active anti-retroviral therapy (HAART) regimens (Boden & Markowitz, *Antimicrob. Agents Chemo.*, 42, 2775-2783, (1998)). Despite their success, the widespread use of PIs has led to the emergence of several thousands of genetically distinct, drug resistant HIV variants, many of which are cross-resistant to the PIs as a class (Richman, *Adv. Exp. Med. Biol.*, 392, 383-395 (1996); Boden & Markowitz (1998), *supra*; Shafer et al. *Ann. Intern. Med.*, 128, 906-911(1998)).

The ability of HAART to provide effective long-term antiretroviral therapy for HIV-1 infection has become a complex issue since 40 to 50% of those who initially achieve favorable viral suppression to undetectable levels experience treatment failure (Grabar et al., *AIDS*, 14, 141-149 (1999); Wit et al., *J. Infect.*

Dis., 179, 790-798 (1999)). Moreover, 10 to 40% of antiviral therapy-naive individuals infected with HIV-1 have persistent viral replication (plasma HIV RNA >500 copies/ml) under HAART (Gulick et al., *N. Engl. J. Med.*, 337, 734-739 (1997); Staszewski et al., *N. Engl. J. Med.*, 341, 1865-1873 (1999)), possibly due to transmission of drug-resistant HIV-1 variants (Wainberg and Friedland, *JAMA*, 279, 1977-1983 (1998)). In addition, it is evident that with these anti-HIV drugs only partial immunologic reconstitution is attained in patients with advanced HIV-1 infection.

The clinical manifestations of drug resistance are viral RNA rebound and decreased CD4 cell-counts in the continued presence of drug. The majority of clinical resistance cases are due to viral adaptation through the generation and selection of mutations in the PR and RT genes. Mutant viruses can be generated through errors in reverse transcription of viral RNA, viral RNA synthesis, and recombination events (Coffin, *Retroviruses* pp.143-144, Cold Spring Harbor Laboratory Press, Plainview (1997)). Mutations within the protease gene that confer clinical drug resistance have emerged for all of the FDA-approved HIV PR inhibitors. The rapid development of drug resistance to PIs, combined with the transmissibility of drug-resistant HIV strains to newly-infected individuals, has resulted in the emergence of a new epidemic of multi-drug resistant AIDS (mdrAIDS). Multi-drug resistant AIDS is caused by a complex spectrum of genetically distinct, infectious new HIV strains that resist most or all forms of currently available treatment.

Accordingly, drug resistant HIV strains represent distinct infectious entities from a therapeutic viewpoint, and pose new challenges for drug design as well as drug treatment of existing infections. Substitutions have been documented in over 45 of the 99 amino acids of the HIV protease monomer in response to protease inhibitor treatment (Mellors, et al., *International Antiviral News*, 3, 8-13(1995); Eastman, et al., *J. Virol.*, 72, 5154-5164(1998); Kozal, et al., *Nat.*

Med., 2, 753-759(1996)). The particular sequence and pattern of mutations selected by PIs is believed to be somewhat drug-specific and often patient-specific, but high level resistance is typified by multiple mutations in the protease gene which give rise to cross-resistance to all of the PIs.

5 The challenge of tackling drug resistance is perhaps best illustrated by considering the dynamics of a typical HIV infection. Approximately 10^{12} virions are produced in an HIV infected individual every day. The mutation rate of HIV is approximately 1 per genome, which numbers 10^4 nucleotide bases. Therefore, every nucleotide in the genome is mutated 10^8 times per
10 round of replication in the patient. This means that all possible single site mutations are present in at least the 0.01% level. Because of this, drugs that can be rendered ineffective with a single mutation from wild type have the shortest effective lifetime in monotherapy settings. The apparently large number of possible mutational pathways, possible mutational combinations,
15 and the danger of generating class-specific cross resistance can make the choice of a subsequent protease inhibitor-containing combination regimen for "salvage therapy" seem very complicated and risky. Even the choice of protease inhibitor with which to initiate therapy, so-called "first-line" therapy, can be a risky enterprise that may inadvertently select for an undesired
20 resistance pathway. Drug-naïve HIV-infected individuals pose even more of a risk for developing resistance to first-line therapies.

For the reasons outlined above, the development of new anti-HIV-1 therapeutics presents formidable challenges different from those in the design of the first line drugs, particularly in regard to consideration of selection
25 pressure mechanisms in addition to the conventional issues of potency, pharmacology, safety, and mechanism of drug action. Indeed, HIV-1 can apparently develop resistance to any existing anti-HIV-1 therapeutic. In particular, the very features that contribute to the specificity and efficacy of

RTIs and PIs provide the virus with a strategy to mount resistance (Erickson and Burt, *Annu. Rev. Pharmacol. Toxicol.*, 36, 545-571 (1996); Mitsuya and Erickson, *Textbook of AIDS Medicine*, pp.751-780, Williams and Wilkins, Baltimore (1999)), and it seems highly likely that this resistance issue will remain problematic for years to come.

Despite numerous studies of drug resistance to PIs, successful strategies to design inhibitors directly targeted against drug resistant HIV have been lacking. Instead, efforts have been directed at identifying drugs with increased potency to wild type virus, and with longer pharmacological half-lives (exemplified by Amprenavir). Another approach has been to develop PIs that are sensitive to pharmacologic "boosting" using Ritonavir, a PI that is also a potent inhibitor of the cytochrome enzymes. The latter approach, exemplified by Kaletra (a Lopinavir/Ritonavir combination), involves higher total drug exposures to PIs which, over time, may lead to long term, serious side effects. Several other PIs have been identified based on efforts to improve plasma half-life and bioavailability. For example, PIs incorporating the 2,5-diamino-3,4-disubstituted-1,6-diphenylhexane isostere are described in Ghosh et. al., *Bioorg. Med. Chem. Lett.*, 8, 687-690 (1998) and U.S. Patent Nos. 5,728,718 (Randad et al.), both of which are incorporated herein by reference in their entirety. HIV PIs, which incorporate the hydroxyethylamine isostere, are described in U.S. Patent Nos. 5,502,060 (Thompson et al.), 5,703,076 (Talley et al.), and 5,475,027 (Talley et al.).

Recent studies have revealed the structural and biochemical mechanisms by which mutations in the PR gene of HIV confer drug resistance in the presence of PIs. An important conclusion that emerges from the body of evidence on resistance to PIs is that HIV variants that exhibit cross-resistance to first-line PIs should be considered to be unique infectious agents. New therapeutic agents need to be developed to successfully treat patients infected with these

viruses. New strategies for drug discovery need to be explored to develop effective protease inhibitor-based treatments for patients with multidrug resistant virus. HIV protease is one the most intensively studied molecular targets in the history of infectious disease.

5 More recently, new mutant strains of HIV have emerged that are resistant to multiple, structurally diverse, experimental and chemotherapeutic HIV PIs. Such *mdrHIV* strains are typically found in infected patients who have undergone treatment with a combination of PIs or with a series of different PIs. The number of reported cases of patients infected with *mdrHIV* is rising
10 steadily. Tragically for these patients, the available options for AIDS chemotherapy and/or HIV management is severely limited or is, otherwise, completely nonexistent.

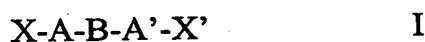
A biochemical fitness profiling strategy has recently been used to identify a novel subclass of potent PIs that have broad-based activity against *mdrHIV*
15 (Gulnik et al., (1995) *supra*; Erickson et al., WO 99/67254; Erickson et al., WO 99/67417).

In view of the foregoing problems, there exists a need for inhibitors against drug resistant and *mdrHIV* strains. Further, there exists a need for inhibitors against drug resistant and multi-drug resistant HIV proteases (*mdrPR*). Further
20 still, there exists a need for inhibitors of HIV that can prevent or slow the emergence of drug resistant and *mdrHIV* strains in infected individuals. Inhibitors with the ability to inhibit *mdrHIV* strains, and to slow the emergence of drug resistant strains in wild type HIV infections, are defined as "resistance-repellent" inhibitors. There also exists a need for robust methods
25 that can be used to design "resistance-repellent" inhibitors.

SUMMARY OF THE INVENTION

The present invention provides such resistance-repellent inhibitors of mdrPR, their compositions, methods of design, and uses thereof for treating mdrHIV and wtHIV infections in salvage therapy and first-line therapy modalities.

5 More particularly, the invention provides HIV protease inhibitors represented by the formula I:



10 where X is a moiety that contains two or more hydrogen bond acceptors capable of interacting with the backbone NH atoms of residues 29 and 30 of an HIV protease, A is a 2-6 atom linker that contains at least one hydrogen bond acceptor that interacts with the flap water, and one hydrogen bond donor that interacts with the backbone CO atom of residue 27, B contains 1-3 atoms that can form hydrogen bonds with either or both carboxylate side chain oxygens of Asp25 and Asp 125 of said protease, A' is a 2-6 atom linker that contains at least one hydrogen bond acceptor that interacts with the flap water; and X' is a moiety that can form one or more hydrogen bonds with the backbone NH atoms of residues 129 and/or 130, provided that the compound of Formula I is not any of the compounds described in *J. Med. Chem.* 39:3278-3290 (1996), in *Bioorg. Med. Chem. Lett.* 8:687-690 (1998), or *Bioorg. Med. Chem. Lett.* 8:979-982 (1998).

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The invention also provides a compound as described above, bound in a complex with wild type or drug resistant mutant forms of HIV-1 protease.

The invention further provides pharmaceutical compositions, comprising an inhibitor as described above, together with a pharmaceutically acceptable additive, excipient, or diluent. The composition may further comprise an

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additional HIV protease inhibitor and/or an HIV reverse transcriptase inhibitor.

The invention further provides methods of treating a patient suffering from HIV infection, comprising administering to the patient a pharmaceutical composition as described above.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 shows the structure of 1.

Figure 2 shows *in vitro* selection of HIV-1 variants resistant to 1 and amprenavir. A laboratory HIV-1 strain, HIV-1NL4-3, was passaged in the presence of increasing concentrations of 1 (○) or amprenavir (●) in MT-2 cells. The selection was carried out in a cell-free manner for a total of 34-64 passages with drug concentrations escalating from 0.0005 to 10 μ M. Nucleotide sequences of proviral DNA were determined using cell lysates of HIV-1-infected MT-2 cells at the termination of each indicated passage.

Figure 3 shows sequence analysis of the protease-encoding region of HIV-1 passaged in the presence of 1. The amino acid sequences of protease deduced from nucleotide sequences of the protease-encoding region of HIV-1 clones determined at nine different passages are illustrated. The fraction of clones examined is indicated on the right. The amino acid sequence of protease of a wild-type pNL4-3 clone is shown as a reference. Identity with this sequence at individual amino acid positions is indicated by dots.

Figure 4 shows a backbone diagram of the dimeric HIV-1 protease. A model of 1 bound in the active site is shown in stick lines. The six residues which are commonly mutated during *in vitro* selection with 1 are indicated by spheres.

Two of these residues lie within the active site (residue 28 and 50), while the other four residues lie outside of the active site (residue 10, 46, 71 and 88).

Figure 5 shows modeling of 1 bound in the active site of HIV-1 protease. Hydrogen bonds are represented as dotted lines.

5 Figure 6 shows the structures of some compounds of general formula I.

Figure 7 shows a set of three-dimensionally-conserved substructures of an HIV protease substrate binding site and the substructure of atoms of an inhibitor interacting with the conserved substructure of the protease.

Table 1 shows the sensitivities of three HIV strains to various HIV drugs.

10 Table 2 shows the PI sensitivities of HIV strains isolated from heavily-drug experienced individuals.

Table 3 shows amino acid substitutions in PR and sensitivities of drug-resistant HIV-1 strains to protease inhibitors.

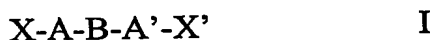
DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

15 The invention provides 'resistance-repellent' retroviral protease inhibitors. A 'resistance-repellent' protease inhibitor ("PI") is a compound that retains inhibitory activity, or potency, over a broad spectrum of related but non-identical retroviral proteases. Examples of resistance-repellent PIs include, but are not limited to, PIs that inhibit wild type HIV-1 protease derived from any
20 clade B virus and 1) a wild type retroviral protease from one or more different retroviruses, such as HIV-2 protease; or 2) mutant HIV-1 proteases with single active site mutations at residues 30, 82 and 84; or 3) mutant HIV-1 proteases with single active site mutations at residues 47, 48, and 50; or 4) mutant HIV-1 proteases with double active site mutations at residues 82 and 84; or 5) mutant
25 HIV-1 proteases with double active site mutations at residues 47 and 48, 47

and 50, or 48 and 50; or 6) mutant HIV-1 proteases with double active site mutations at residues 48 and 82, 48 and 90, or 82 and 90; or 7) mutant HIV-1 proteases with three or more active site mutations in any combination at residues 32, 47, 48, 50, 82, 84 or 90.

5 The term "pharmaceutically effective amount" refers to an amount effective in treating a virus infection, for example an HIV infection, in a patient either as monotherapy or in combination with other agents. The term "treating" as used herein refers to the alleviation of symptoms of a particular disorder in a patient or the improvement of an ascertainable measurement associated with a particular disorder. The term "prophylactically effective amount" refers to an amount effective in preventing a virus infection, for example an HIV infection, in a patient. As used herein, the term "patient" refers to a mammal, including a human.

10 The applicants have found that compounds having the general formula I are effective against a wide variety of PI-resistant HIV strains



where X is a moiety that contains two or more hydrogen bond acceptors capable of interacting with the backbone NH atoms of residues 29 and 30 of an HIV protease, A is a 2-6 atom linker that contains at least one hydrogen bond acceptor that interacts with the flap water, and one hydrogen bond donor that interacts with the backbone CO atom of residue 27, B contains 1-3 atoms that can form hydrogen bonds with either or both carboxylate side chain oxygens of Asp25 and Asp 125 of said protease, A' is a 2-6 atom linker that contains at least one hydrogen bond acceptor that interacts with the flap water; and X' is a moiety that can form one or more hydrogen bonds with the backbone NH atoms of residues 129 and/or 130. Some compounds conforming to this

general formula have been described and the present invention specifically excludes those compounds.

Resistance-repellent PIs should generally also retain inhibitory activity, or potency, over a broad spectrum of related but non-identical retroviruses. In particular, resistance-repellent PIs should inhibit all HIV-1 virus strains that contain a gene sequence of the protease region of the HIV-1 pol gene that is typified by one or more 'wild type' strains derived from clade B and: 1) HIV-1 virus strains that contain a gene sequence of the protease region of the HIV-1 pol gene derived from wild type, non-clade B viruses; or 2) wild type HIV-2 virus strains; or 3) HIV-1 virus strains derived from patients who are infected with HIV-1 that contain mutations in the protease gene.

Comparative analysis of the x-ray crystal structures of complexes of different inhibitors bound to wild type and mutant forms of HIV protease has led the applicants to the insight that a substructure in the active site of HIV protease is structurally-conserved. It has also been discovered that compositions that form selective interactions with this conserved substructure, have attributes of resistance-repellent inhibitors of HIV protease. This insight has not been previously described. These insights have led the applicants to design improved HIV PI compounds that are effective against multidrug resistant HIV strains.

In a preferred embodiment, the instant invention provides an HIV protease inhibitor represented by a formula:



wherein,

X is a moiety that contains two or more hydrogen bond acceptors capable of interacting with the backbone NH atoms of residues 29 and 30 of said protease;

5 A is a 2-6 atom linker that contains at least one hydrogen bond acceptor that interacts with the flap water, and one hydrogen bond donor that interacts with the backbone CO atom of residue 27 of said protease;

B contains 1-3 atoms that can form hydrogen bonds with either or both carboxylate side chain oxygens of Asp25 and Asp 125 of said protease;

10 A' is a 2-6 atom linker that contains at least one hydrogen bond acceptor that interacts with a flap water of said protease;

X' is a moiety that can form one or more hydrogen bonds with the backbone NH atoms of residues 129 and/or 130 of said protease.

In a particular embodiment the invention provides an HIV protease inhibitor represented by the formula I:



I

wherein X is a moiety that contains two or more hydrogen bond acceptors capable of interacting with the backbone NH atoms of residues 29 and 30 of an HIV protease;

20 A is a 2-6 atom linker that contains at least one hydrogen bond acceptor that interacts with a flap water of said protease, and one hydrogen bond donor that interacts with the backbone CO atom of residue 27 of said protease;

B contains 1-3 atoms that can form hydrogen bonds with either or both carboxylate side chain oxygens of Asp25 and Asp 125 of said protease;

A' is a 2-6 atom linker that contains at least one hydrogen bond acceptor that interacts with the flap water of said protease; and

X' is a moiety that can form one or more hydrogen bonds with the backbone NH atoms of residues 129 and/or 130 of said protease; provided that the compound of Formula I is not any of the compounds described in *J. Med. Chem.* 39:3278-3290 (1996), in *Bioorg. Med. Chem. Lett.* 8:687-690 (1998), or *Bioorg. Med. Chem. Lett.* 8:979-982 (1998).

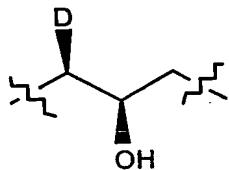
In another embodiment, the invention provides an HIV protease inhibitor represented by a formula:

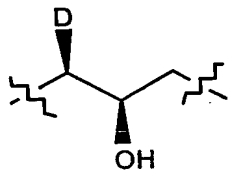


wherein:

X is independently a 5-7 membered non-aromatic monocyclic heterocycle, wherein said heterocycle is optionally fused with 1 or 2 3-7 membered non-aromatic monocyclic heterocycles, wherein said 5-7 membered non-aromatic monocyclic heterocycle is substituted by at least a group R4 on a carbon of said heterocycle adjacent to a heteroatom wherein R4 may optionally be part of the fused heterocycles; and wherein any of said heterocyclic ring systems has one or more heteroatoms selected from N, O, and S, wherein N is optionally substituted by R2 and S is optionally substituted by one or two oxygen atoms, and wherein any of said ring systems is optionally substituted 1 to 6 times by R5;

A is ZCONH, ZCOCONH, ZS(O)₂NH, ZP(O)(V)NH, CONH, COCONH, S(O)₂NH, P(O)(V)NH, wherein Z is O, NR₂, C(R₂)₂, and V is OR₂, NR₂;



B is , wherein D is selected from C1-C6 alkyl, C2-C4 alkenyl optionally substituted with one or more groups selected from C3-C7 cycloalkyl, C5-C7 cycloalkenyl, OR₂, SR₂, NHR₂, OR₃, SR₃, NHR₃, OR₆, SR₆, or NHR₆;

5 A' is N(D')E', wherein D' is selected from C1-C15 alkyl, C2-C15 alkenyl or C2-C15 alkynyl, and E' is -CO- or -SO₂-;

X' is selected from the group consisting of R₂, R₃, and R₆, provided that when X' is H, E' is not -SO₂-;

R₂ is H or C1-C6 alkyl optionally substituted by R₃, R₅, or R₆,

10 R₃ is C2-C6 alkenyl, C2-C6 alkynyl, C3-C8 cycloalkyl, C5-C8 cycloalkenyl, or heterocyclo, which groups may be optionally substituted with one or more substituents selected from the group consisting of -OR₂, C(O)N(R₂)₂, S(O)_nN(R₂)₂, CN, SR₂, SO_nR₂, COR₂, CO₂R₂ or NR₂C(O)R₂, R₅, and R₇;

15 R₄ is N(R₈)₂, NHOH, N(R₈)COR₈, NR₈S(O)_nR₈, NR₈C[=N(R₈)]N(R₈)₂, N(R₈)N(R₈)C(O)R₈, NR₈PO_nN(R₈)₂, NR₈PO_nOR₈, OH, OR₈, OC(O)R₈, OC(S)R₈, OC(O)N(R₈)₂, OC(S)N(R₈)₂, OPO_n(R₈)₂, R₂OH, R₂-halo, CN, COR₈, CO₂R₈, CON(R₈)₂, C(O)N(R₈)N(R₈)₂, S(O)_nR₈, SO₂N(R₈)₂, halo, NO₂, or SR₈;

20 R₅ is OH, OR₈, N(R₈)₂, NHOH, N(R₈)COR₈, NR₈S(O)_nR₈, NR₈C[=N(R₈)]N(R₈)₂, N(R₈)N(R₈)C(O)R₈, NR₈PO_nN(R₈)₂, NR₈PO_nOR₈, R₂OH, R₂-halo, CN, COR₈, CO₂R₈, CON(R₈)₂, C(O)N(R₈)N(R₈)₂, S(O)_nR₈, SO₂N(R₈)₂, halo, NO₂, SR₈, oxo, =N-OH, =N-OR₈, =N-N(R₈)₂, =NR₈,

$=\text{NNR}8\text{C}(\text{O})\text{N}(\text{R}8)_2$, $=\text{NNR}8\text{C}(\text{O})\text{OR}8$, $=\text{NNR}8\text{S}(\text{O})_n\text{N}(\text{R}8)_2$, or
 $=\text{NNR}8\text{S}(\text{O})_n(\text{R}8)$, $=\text{NNR}8\text{C}(\text{O})\text{R}8$,

or R5 is C2-C6 alkenyl, C2-C6 alkynyl, C3-C8 cycloalkyl, C5-C8
 cycloalkenyl, or heterocyclo, which groups may be optionally substituted with
 one or more substituents selected from the group consisting of -OR2,
 C(O)NR2, S(O)_nN(R2)₂, CN, SR2, SO_nR2, COR2, CO₂R2 or NR2C(O)R2,
 R5, and R7,

or R5 is C(O)R2, C(O)R3, C(O)R6, C(S)R2, C(S)R3, C(S)R6,
 C(Z)N(R2)₂, C(Z)N(R3)₂, C(Z)N(R6)₂, C(Z)NR2R3, C(Z)NR2R6,
 C(Z)NR3R6, CO₂R2; provided R2 is not H; CO₂R3, or CO₂R6;

R6 is aryl or heteroaryl, wherein said aryl or heteroaryl may be optionally
 substituted with one or more groups selected from the group consisting of aryl,
 heteroaryl, R2, R3, and R4;

R7 is C(O)R2, C(O)R3, C(O)R6, C(S)R2, C(S)R3, C(S)R6,
 C(Z)N(R2)₂, C(Z)N(R3)₂, C(Z)N(R6)₂, C(Z)NR2R3, C(Z)NR2R6,
 C(Z)NR3R6, or CO₂R2; provided R2 is not H; CO₂R3, or CO₂R6

R8 is H or C1-C6 alkyl optionally substituted by R3, R5, or R6,

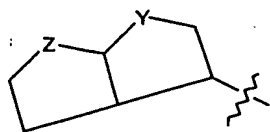
or R8 is C2-C6 alkenyl, C2-C6 alkynyl, C3-C8 cycloalkyl, C5-C8
 cycloalkenyl, or heterocyclo, which groups may be optionally substituted with
 one or more substituents selected from the group consisting of -OR2,
 C(O)NR2, S(O)_nN(R2)₂, CN, SR2, SO_nR2, COR2, CO₂R2 or NR2C(O)R2,
 R5, and R7,

or R8 is aryl or heteroaryl, wherein said aryl or heteroaryl may be optionally
 substituted with one or more groups selected from the group consisting of aryl,
 heteroaryl, R2, R3, R4, and R6;

Z is O, S;

each n is independently an integer between 1-2; its stereoisomeric forms; and its pharmacologically acceptable salts.

Preferably, X is



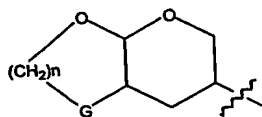
wherein

Y is O, NH, or S;

Z is O, NH, or S; and

wherein any ring carbon is optionally substituted by R₂, R₃, R₅, R₆.

10 Preferably X is



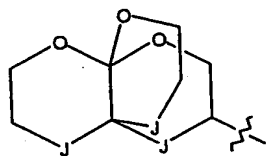
wherein

G is C, O, NR₂, or S;

n is an integer between 1-2; and

15 wherein any ring carbon is optionally substituted by R₂, R₃, R₅, R₆.

Preferably, X is

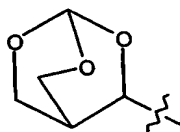


wherein

J is independently CH₂, or O, or J is a bond; and

wherein any ring carbon is optionally substituted by R₂, R₃, R₅, R₆.

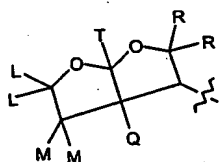
Preferably, X is



wherein any ring carbon is optionally substituted by R₂, R₃, R₅, or R₆.

5

Preferably, X is



wherein

each L is independently H, lower alkyl, oxo, or L forms a carbocyclic or heterocyclic ring with M;

10

each M is independently H, OH, chloro, fluoro, or M forms a carbocyclic or heterocyclic ring with Q, provided that if one M is OH, the other M is not OH;

Q is H, OH, amino, lower alkyl, alkylamino, alkoxy, halo, or forms a 3-7-membered carbocyclic or heterocyclic ring together with T;

15

each R is independently H, OH, lower alkyl, halo, or spirocyclopropyl, provided that if one R is OH, the other R is not OH;

T is H or F, or T forms a carbocyclic or heterocyclic ring together with C;

In another preferred embodiment, the invention also provides an HIV protease inhibitor represented by a formula:

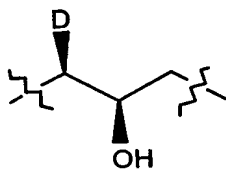


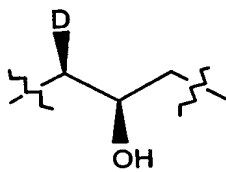
20

wherein:

X is a 5-7 membered non-aromatic monocyclic heterocycle, wherein said heterocycle is fused with at least one 3-7 membered non-aromatic monocyclic heterocycle to form a polycyclic system, preferably bicyclic, wherein at least one carbon atom is substituted by two heteroatoms; and wherein any of said heterocyclic ring systems contains one or more heteroatoms selected from O, N, S; wherein any nitrogen forming part of the heterocycles may optionally be substituted by R₂, R₃, R₆, R₇ or O; wherein any sulfur may be optionally be substituted by one or two oxygen atoms; and any of said ring systems optionally contains 1 to 6 substituents selected from the group consisting of R₂, R₃, R₅, and R₆;

A is ZCZNH; wherein Z is independently NR₂, O, or S;



B is , wherein D is alkyl, alkenyl, alkynyl, aryl, cycloalkyl, or aralkyl optionally substituted by alkyl, halo, nitro, cyano, CF₃, O-alkyl or S-alkyl;

A' is N(D')E', wherein D' is alkyl, alkenyl, alkynyl aryl, cycloalkyl, or aralkyl optionally substituted by alkyl, halo, CF₃, and E' is SO₂;

X' is selected from the group consisting of aryl and heteroaryl, which are substituted with one or more of the following groups:

OR₃, OR₆, OR₇, OR₂ provided R₂ is not H or unsubstituted alkyl;

alkyl substituted by R₃, R₅, R₆ provided R₅ is not halo;

2-C₆ alkenyl, C₂-C₆ alkynyl, C₃-C₈ cycloalkyl, C₅-C₈ cycloalkenyl, and heterocyclo, which groups may be optionally substituted with one or more

substituents selected from the group consisting of $-OR_2$, $C(O)N(R_2)_2$, $S(O)_nN(R_2)_2$, CN , SR_2 , SO_nR_2 , COR_2 , CO_2R_2 or $NR_2C(O)R_2$, R_5 , and R_7 ;

aryl or heteroaryl, wherein said aryl or heteroaryl may be optionally substituted with one or more groups selected from the group consisting of aryl, heteroaryl, R_2 , R_3 , R_4 , and R_6 ;

C3-C7 cycloalkyl substituted by R_2 , R_3 , R_5 , R_6 ; provided R_2 is not H;

CO_2H , R_7 provided Z is N, O, S and provided R_2 is not H or unsubstituted alkyl;

NR_3R_3 , NR_6R_6 , NR_7R_7 , NR_3R_6 , NR_6R_7 , NR_3R_7 , NR_2R_3 , NR_2R_6 , NR_2R_7 , NR_2R_2 provided R_2 is not H or unsubstituted alkyl;

$SO_nN(R_2)_2$, $SO_nN(R_3)_2$, $SO_nN(R_6)_2$, $SO_nN(R_7)_2$, $SO_nNR_2R_3$, $SO_nNR_2R_6$, $SO_nNR_2R_7$, $SO_nNR_3R_6$, $SO_nNR_3R_7$, $SO_nNR_6R_7$, wherein $n=1$ or 2 ;

$S(O)_nR_2$, $S(O)_nR_3$, $S(O)_nR_6$, provided R_2 is not H or methyl; and n is 0, 1 or 2;

R_2 is H or C1-C6 alkyl optionally substituted by R_3 , R_5 , or R_6 ,

R_3 is C2-C6 alkenyl, C2-C6 alkynyl, C3-C8 cycloalkyl, C5-C8 cycloalkenyl, or heterocyclo, which groups may be optionally substituted with one or more substituents selected from the group consisting of $-OR_2$, $C(O)N(R_2)_2$, $S(O)_nN(R_2)_2$, CN , SR_2 , SO_nR_2 , COR_2 , CO_2R_2 or $NR_2C(O)R_2$, R_5 , and R_7 ;

R_4 is $N(R_8)_2$, $NHOH$, $N(R_8)COR_8$, $NR_8S(O)_nR_8$, $NR_8C[=N(R_8)]N(R_8)_2$, $N(R_8)N(R_8)C(O)R_8$, $NR_8PO_nN(R_8)_2$, $NR_8PO_nOR_8$, OH , OR_8 , $OC(O)R_8$, $OC(S)R_8$, $OC(O)N(R_8)_2$, $OC(S)N(R_8)_2$, $OPO_n(R_8)_2$,

R₂OH, R₂-halo, CN, COR₈, CO₂R₈, CON(R₈)₂, C(O)N(R₈)N(R₈)₂, S(O)_nR₈, SO₂N(R₈)₂, halo, NO₂, or SR₈;

R₅ is OH, OR₈, N(R₈)₂, NHOH, N(R₈)COR₈, NR₈S(O)_nR₈, NR₈C[=N(R₈)]N(R₈)₂, N(R₈)N(R₈)C(O)R₈, NR₈PO_nNR₈R₈, NR₈PO_nOR₈,
 5 R₂OH, R₂-halo, CN, COR₈, CO₂R₈, CON(R₈)₂, C(O)N(R₈)N(R₈)₂, S(O)_nR₈, SO₂N(R₈)₂, halo, NO₂, SR₈, oxo, =N-OH, =N-OR₈, =N-N(R₈)₂, =NR₈, =NNR₈C(O)N(R₈)₂, =NNR₈C(O)OR₈, =NNR₈S(O)_nN(R₈)₂, =NNR₈S(O)_n(R₈), or =NNR₈S(O)_n(R₈),

or R₅ is C₂-C₆ alkenyl, C₂-C₆ alkynyl, C₃-C₈ cycloalkyl, C₅-C₈ cycloalkenyl, or heterocyclo, which groups may be optionally substituted with
 10 one or more substituents selected from the group consisting of -OR₂, C(O)NR₂, S(O)_nN(R₂)₂, CN, SR₂, SO_nR₂, COR₂, CO₂R₂ or NR₂C(O)R₂, R₅, and R₇,

or R₅ is C(O)R₂, C(O)R₃, C(O)R₆, C(S)R₂, C(S)R₃, C(S)R₆, C(Z)N(R₂)₂, C(Z)N(R₃)₂, C(Z)N(R₆)₂, C(Z)NR₂R₃, C(Z)NR₂R₆, C(Z)NR₃R₆, CO₂R₂;
 15 provided R₂ is not H; CO₂R₃, or CO₂R₆;

R₆ is aryl or heteroaryl, wherein said aryl or heteroaryl may be optionally substituted with one or more groups selected from the group consisting of aryl, heteroaryl, R₂, R₃, and R₄;

R₇ is C(O)R₂, C(O)R₃, C(O)R₆, C(S)R₂, C(S)R₃, C(S)R₆, C(Z)N(R₂)₂, C(Z)N(R₃)₂, C(Z)N(R₆)₂, C(Z)NR₂R₃, C(Z)NR₂R₆, C(Z)NR₃R₆, CO₂R₂; provided R₂ is not H; CO₂R₃, or CO₂R₆

R₈ is H and C₁-C₆ alkyl optionally substituted by R₃, R₅, or R₆,

or R₈ is C₂-C₆ alkenyl, C₂-C₆ alkynyl, C₃-C₈ cycloalkyl, C₅-C₈ cycloalkenyl, and heterocyclo, which groups may be optionally substituted

with one or more substituents selected from the group consisting of -OR₂, C(O)NHR₂, S(O)_nN(R₂)(R₂), CN, SR₂, SOnR₂, COR₂, CO₂R₂ or NR₂C(O)R₂, R₅, and R₇;

or R₈ is aryl or heteroaryl, wherein said aryl or heteroaryl may be optionally substituted with one or more groups selected from the group consisting of aryl, heteroaryl, R₂, R₃, R₄, and R₆;

Z is O, S;

each n is independently an integer between 1-2;

its stereoisomeric forms; and its pharmacologically acceptable salts.

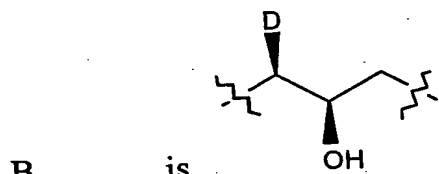
In another preferred embodiment, the invention also provides an HIV protease inhibitor represented by a formula:



wherein:

X is tetrahydrofurodihydrofuranyl, tetrahydrofurotetrahydrofuranyl, tetrahydropyranotetrahydrofuranyl or tetrahydropyranodihydrofuranyl;

A is OCONH;



, wherein D is alkyl, alkenyl, alkynyl, aryl, cycloalkyl, or aralkyl optionally substituted by alkyl, halo, nitro, cyano, CF₃, O-alkyl or S-alkyl;

A' is N(D')E', wherein D' is alkyl, alkenyl, alkynyl aryl, cycloalkyl, or aralkyl optionally substituted by alkyl, halo, or CF₃, and E' is -SO₂-;

X' is selected from the group consisting of aryl and heteroaryl, which are substituted with one or more groups selected from the group consisting of:

5 OR₃, OR₆, OR₇, or OR₂ provided R₂ is not H or unsubstituted alkyl;

alkyl substituted by R₃, R₅, or R₆ provided R₅ is not halo;

10 C₂-C₆ alkenyl, C₂-C₆ alkynyl, C₃-C₈ cycloalkyl, C₅-C₈ cycloalkenyl, and heterocyclo, which groups may be optionally substituted with one or more substituents selected from the group consisting of -OR₂, C(O)NHR₂, S(O)_nN(R₂)(R₂), CN, SR₂, SO_nR₂, COR₂, CO₂R₂ or NR₂C(O)R₂, R₅, and R₇;

aryl or heteroaryl, wherein said aryl or heteroaryl may be optionally substituted with one or more groups selected from the group consisting of aryl, heteroaryl, R₂, R₃, R₄, and R₆;

15 C₃-C₇ cycloalkyl substituted by R₂, R₃, R₅, or R₆; provided R₂ is not H;

CO₂H, or R₇ where Z= N, O, S and provided R₂ is not H or unsubstituted alkyl

NR₃R₃, NR₆R₆, NR₇R₇, NR₃R₆, NR₆R₇, NR₃R₇, NR₂R₃, NR₂R₆, NR₂R₇, NR₂R₂ provided R₂ is not H or unsubstituted alkyl;

20 SO_nN(R₂)₂, SO_nN(R₃)₂, SO_nN(R₆)₂, SO_nN(R₇)₂, SO_nNR₂R₃, SO_nNR₂R₆, SO_nNR₂R₇, SO_nNR₃R₆, SO_nNR₃R₇, SO_nNR₆R₇, n= 1 or 2;

S(O)_nR₂, S(O)_nR₃, S(O)_nR₆, provided R₂ is not H or methyl; n is 0, 1 or 2;

R₂ is H or C₁-C₆ alkyl optionally substituted by R₃, R₅, or R₆,

R3 is C2-C6 alkenyl, C2-C6 alkynyl, C3-C8 cycloalkyl, C5-C8 cycloalkenyl, and heterocyclo, which groups may be optionally substituted with one or more substituents selected from the group consisting of -OR2, C(O)N(R2)₂, S(O)_nN(R2)(R2), CN, SR2, SO_nR2, COR2, CO₂R2 or NR2C(O)R2, R5, and R7;

R4 is N(R8)₂, NHOH, N(R8)COR8, NR8S(O)_nR8, NR8C[=N(R8)]N(R8)₂, N(R8)N(R8)C(O)R8, NR8PO_nNR8R8, NR8PO_nOR8, OH, OR8, OC(O)R8, OC(S)R8, OC(O)N(R8)₂, OC(S)N(R8)₂, OPO_n(R8)₂R2OH, R2-halo, CN, COR8, CO₂R8, CON(R8)₂, C(O)N(R8)N(R8)₂, S(O)_nR8, SO₂N(R8)₂, halo, NO₂, or SR8;

R5 is OH, OR8, N(R8)₂, NHOH, N(R8)COR8, NR8S(O)_nR8, NR8C[=N(R8)]N(R8)₂, N(R8)N(R8)C(O)R8, NR8PO_nN(R8)₂, NR8PO_nOR8, R2OH, R2-halo, CN, COR8, CO₂R8, CON(R8)₂, C(O)N(R8)N(R8)₂, S(O)_nR8, SO₂N(R8)₂, halo, NO₂, SR8, oxo, =N-OH, =N-OR8, =N-N(R8)₂, =NR8, =NNR8C(O)N(R8)₂, =NNR8C(O)OR8, =NNR8S(O)_nN(R8)₂, or =NNR8S(O)_n(R8), =NNR8C(O)R8,

or R5 is C2-C6 alkenyl, C2-C6 alkynyl, C3-C8 cycloalkyl, C5-C8 cycloalkenyl, or heterocyclo, which groups may be optionally substituted with one or more substituents selected from the group consisting of -OR2, C(O)NR2, S(O)_nN(R2)₂, CN, SR2, SO_nR2, COR2, CO₂R2 or NR2C(O)R2, R5, and R7,

or R5 is C(O)R2, C(O)R3, C(O)R6, C(S)R2, C(S)R3, C(S)R6, C(Z)N(R2)₂, C(Z)N(R3)₂, C(Z)N(R6)₂, C(Z)NR2R3, C(Z)NR2R6, C(Z)NR3R6, CO₂R2; provided R2 is not H; CO₂R3, or CO₂R6;

R6 is aryl or heteroaryl, wherein said aryl or heteroaryl may be optionally substituted with one or more groups selected from the group consisting of aryl, heteroaryl, R2, R3, and R4;

R7 is C(O)R2, C(O)R3, C(O)R6, C(S)R2, C(S)R3, C(S)R6, C(Z)N(R2)₂, C(Z)N(R3)₂, C(Z)N(R6)₂, C(Z)NR2R3, C(Z)NR2R6, C(Z)NR3R6, CO₂R2; provided R2 is not H; CO₂R3, or CO₂R6

R8 is H or C1-C6 alkyl optionally substituted by R3, R5, or R6,

or R8 is C2-C6 alkenyl, C2-C6 alkynyl, C3-C8 cycloalkyl, C5-C8 cycloalkenyl, or heterocyclo, which groups may be optionally substituted with one or more substituents selected from the group consisting of -OR2, C(O)NR2, S(O)_nN(R2)₂, CN, SR2, SO_nR2, COR2, CO₂R2 or NR2C(O)R2, R5, and R7,

or R8 is aryl or heteroaryl, wherein said aryl or heteroaryl may be optionally substituted with one or more groups selected from the group consisting of aryl, heteroaryl, R2, R3, R4, and R6;

Z is O, S;

each n is independently an integer between 1-2; its stereoisomeric forms; and its pharmacologically acceptable salts.

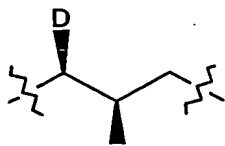
In another preferred embodiment, the invention also provides anHIV protease inhibitor represented by a formula:



wherein:

X is tetrahydrofurotetrahydrofuranyl;

A is OCONH;



B is , wherein D is benzyl

A' is N(D')E', wherein D' is isobutyl and E' is -SO₂-;

X' is selected from the group consisting of aryl and heteroaryl, which
5 are substituted with one or more groups selected from the group consisting of:

OR₃, OR₆, OR₇, OR₂ provided R₂ is not H or unsubstituted alkyl;

alkyl substituted by R₃, R₅, R₆ provided R₅ is not halo;

C₂-C₆ alkenyl, C₂-C₆ alkynyl, C₃-C₈ cycloalkyl, C₅-C₈ cycloalkenyl, and
10 heterocyclo, which groups may be optionally substituted with one or more
substituents selected from the group consisting of -OR₂, C(O)NHR₂,
S(O)_nN(R₂)(R₂), CN, SR₂, SO_nR₂, COR₂, CO₂R₂ NR₂C(O)R₂, R₅, and R₇;

aryl or heteroaryl, wherein said aryl or heteroaryl may be optionally
substituted with one or more groups selected from the group consisting of aryl,
heteroaryl, R₂, R₃, R₄, and R₆;

15 C₃-C₇ cycloalkyl substituted by R₂, R₃, R₅, R₆; provided R₂ is not H;

CO₂H, R₇ where Z= N, O, or S provided R₂ is not H or unsubstituted alkyl

NR₃R₃, NR₆R₆, NR₇R₇, NR₃R₆, NR₆R₇, NR₃R₇, NR₂R₃, NR₂R₆,
NR₂R₇, or NR₂R₂ provided R₂ is not H or unsubstituted alkyl;

20 SO_nN(R₂)₂, SO_nN(R₃)₂, SO_nN(R₆)₂ SO_nN(R₇)₂, SO_nNR₂R₃, SO_nNR₂R₆,
SO_nNR₂R₇, SO_nNR₃R₆, SO_nNR₃R₇, or SO_nNR₆R₇, wherein n= 1 or 2;

S(O)_nR₂, S(O)_nR₃, S(O)_nR₆, provided R₂ is not H or methyl; wherein n is 0, 1 or 2;

R₂ is H and C1-C6 alkyl optionally substituted by R₃, R₅, or R₆,

R₃ is C2-C6 alkenyl, C2-C6 alkynyl, C3-C8 cycloalkyl, C5-C8 cycloalkenyl, or heterocyclo, which groups may be optionally substituted with one or more substituents selected from the group consisting of -OR₂, C(O)N(R₂)₂, S(O)_nN(R₂)₂, CN, SR₂, SO_nR₂, COR₂, CO₂R₂ or NR₂C(O)R₂, R₅, and R₇;

R₄ is N(R₈)₂, NHOH, N(R₈)COR₈, NR₈S(O)_nR₈, NR₈C[=N(R₈)]N(R₈)₂, N(R₈)N(R₈)C(O)R₈, NR₈PO_nN(R₈)₂, NR₈PO_nOR₈, OH, OR₈, OC(O)R₈, OC(S)R₈, OC(O)N(R₈)₂, OC(S)N(R₈)₂, OPO_n(R₈)₂, R₂OH, R₂-halo, CN, COR₈, CO₂R₈, CON(R₈)₂, C(O)N(R₈)N(R₈)₂, S(O)_nR₈, SO₂N(R₈)₂, halo, NO₂, or SR₈;

R₅ is OH, OR₈, N(R₈)₂, NHOH, N(R₈)COR₈, NR₈S(O)_nR₈, NR₈C[=N(R₈)]N(R₈)₂, N(R₈)N(R₈)C(O)R₈, NR₈PO_nN(R₈)₂, NR₈PO_nOR₈, R₂OH, R₂-halo, CN, COR₈, CO₂R₈, CON(R₈)₂, C(O)N(R₈)N(R₈)₂, S(O)_nR₈, SO₂N(R₈)₂, halo, NO₂, SR₈, oxo, =N-OH, =N-OR₈, =N-N(R₈)₂, =NR₈, =NNR₈C(O)N(R₈)₂, =NNR₈C(O)OR₈, =NNR₈S(O)_nN(R₈)₂, or =NNR₈S(O)_n(R₈), =NNR₈C(O)R₈,

or R₅ is C2-C6 alkenyl, C2-C6 alkynyl, C3-C8 cycloalkyl, C5-C8 cycloalkenyl, or heterocyclo, which groups may be optionally substituted with one or more substituents selected from the group consisting of -OR₂, C(O)NR₂, S(O)_nN(R₂)₂, CN, SR₂, SO_nR₂, COR₂, CO₂R₂ or NR₂C(O)R₂, R₅, and R₇,

or R5 is C(O)R2, C(O)R3, C(O)R6, C(S)R2, C(S)R3, C(S)R6, C(Z)N(R2)₂, C(Z)N(R3)₂, C(Z)N(R6)₂, C(Z)NR2R3, C(Z)NR2R6, C(Z)NR3R6, CO₂R2; provided R2 is not H; CO₂R3, or CO₂R6;

5 R6 is aryl or heteroaryl, wherein said aryl or heteroaryl may be optionally substituted with one or more groups selected from the group consisting of aryl, heteroaryl, R2, R3, and R4;

R7 is C(O)R2, C(O)R3, C(O)R6, C(S)R2, C(S)R3, C(S)R6, C(Z)N(R2)₂, C(Z)N(R3)₂, C(Z)N(R6)₂, C(Z)NR2R3, C(Z)NR2R6, C(Z)NR3R6, CO₂R2; provided R2 is not H; CO₂R3, or CO₂R6

10 R8 is H or C1-C6 alkyl optionally substituted by R3, R5, or R6,

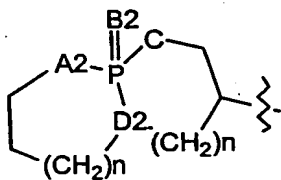
or R8 is C2-C6 alkenyl, C2-C6 alkynyl, C3-C8 cycloalkyl, C5-C8 cycloalkenyl, or heterocyclo, which groups may be optionally substituted with one or more substituents selected from the group consisting of -OR2, C(O)NR2, S(O)_nN(R2)₂, CN, SR2, SO_nR2, COR2, CO₂R2 or NR2C(O)R2, R5, and R7,

15 or R8 is aryl or heteroaryl, wherein said aryl or heteroaryl may be optionally substituted with one or more groups selected from the group consisting of aryl, heteroaryl, R2, R3, R4, and R6;

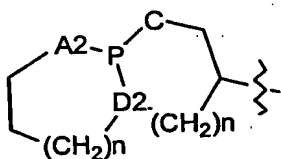
Z is O, S;

20 each n is independently an integer between 1-2; its stereoisomeric forms; and its pharmacologically acceptable salts.

Preferably, X is



or

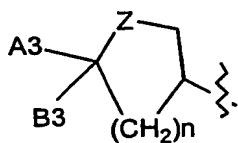


wherein A2, B2, and C are each independently O, NR₂, or S;

5 D2 is CH or N; and

wherein any ring carbon is optionally substituted by R₂, R₃, R₅, or R₆.

Preferably, X is



wherein

10 A3 is H, F or alkoxy;

B3 is F, alkoxy, lower alkyl, or A and B can form a 3-7 membered heterocyclic ring;

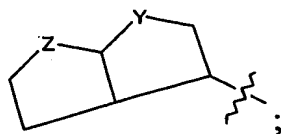
Z is O, NR₂, or S;

n is an integer between 1-3; and

15 wherein any ring carbon is optionally substituted by R₂, R₃, R₅, R₆.

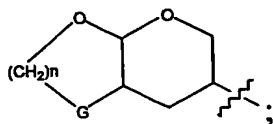
With regard to X, X may also be a 5-7 membered non-aromatic monocyclic heterocycle, wherein said heterocycle is optionally fused or bridged with one or more 3-7 membered non-aromatic monocyclic heterocycle to form a polycyclic system, wherein any of said heterocyclic ring systems contains one or more heteroatoms selected from O, N, S, or P; wherein any nitrogen forming part of the heterocycles may optionally be substituted by R₂, R₃, R₆, R₇ or O; wherein any sulfur may be optionally be substituted by one or two oxygen atoms; wherein any P may be optionally be substituted by one or more of O NR₂, or S, and any of said ring systems optionally contains 1 to 6 substituents selected from the group consisting of R₂, R₃, R₅, and R₆.

X may also be



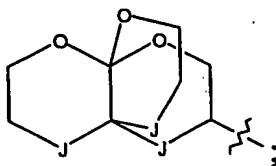
wherein, Y is O, NH, or S; Z is O, NH, or S; and wherein any ring carbon is optionally substituted by R₂, R₃, R₅, or R₆.

X may also be



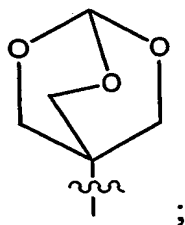
wherein G is C, O, NR₂, or S; n is an integer between 1-2; and wherein any ring carbon is optionally substituted by R₂, R₃, R₅, or R₆.

X may also be



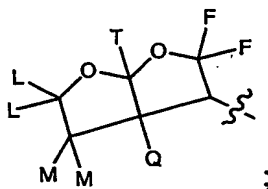
wherein J is independently CH₂, or O, and wherein any ring carbon is optionally substituted by R₂, R₃, R₅, or R₆.

X may also be



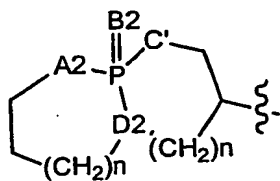
wherein any ring carbon is optionally substituted by R₂, R₃, R₅, or R₆.

X may also be

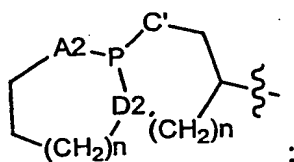


wherein each L is independently H, lower alkyl, oxo, or L forms a carbocyclic or heterocyclic ring with M; each M is independently H, OH, chloro, fluoro, or M forms a carbocyclic or heterocyclic ring with Q; provided that if one M is OH, the other M is not OH; Q is H, OH, amino, lower alkyl, alkylamino, alkoxy, halo, or forms a 3-7-membered carbocyclic or heterocyclic ring together with T; each F is independently H, OH, lower alkyl, halo, or spirocyclopropyl, provided that if one R is OH, the other R is not OH; T is H or F, or T forms a carbocyclic or heterocyclic ring together with F.

X may also be

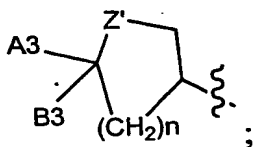


or



- 5 wherein A2, B2, and C' are each independently O, NR₂, or S; D2 is CH or N; and n is an integer between 1 and 2.

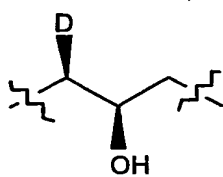
X may also be

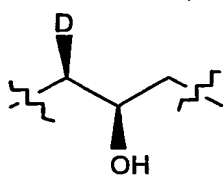


- 10 wherein A3 is H, F or alkoxy; B3 is F, alkoxy, lower alkyl, or A3 and B3 can form a 3-7 membered heterocyclic ring; Z' is O, NR₂, or S; and n is an integer between 1-3.

X is preferably tetrahydrofurodihydrofuranyl, tetrahydrofuro-
tetrahydrofuranyl, tetrahydropyrano-tetrahydrofuranyl or
tetrahydropyranodihydrofuranyl. More preferably, X is
15 tetrahydrofurotetrahydro-furanyl.

With regard to A, A may be ZCZNH, ZCOCONH, ZS(O)₂NH, ZP(O)(V)NH, CONH, COCONH, S(O)₂NH, P(O)(V)NH, wherein Z is NR₂, O, S, or C(R₂)₂, and V is OR₂ or NR₂. A is preferably OCONH.



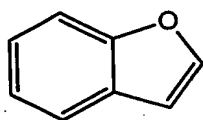
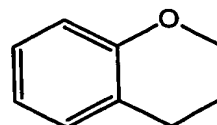
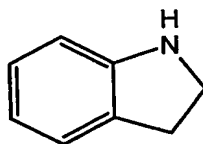
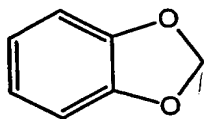
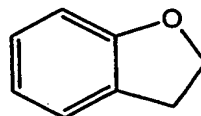
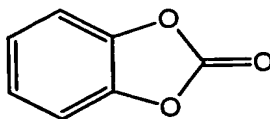
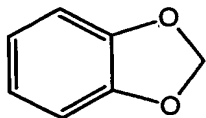
With regard to B, B may be , wherein D is selected from alkyl, alkenyl, alkynyl, aryl, cycloalkyl, or aralkyl optionally substituted with one or more groups selected from alkyl, halo, nitro, cyano, CF₃, C3-C7 cycloalkyl, C5-C7 cycloalkenyl, R₆, OR₂, SR₂, NHR₂, OR₃, SR₃, NHR₃, OR₆, SR₆, or NHR₆.

With regard to A', A' may be N(D')E', wherein D' is selected from alkyl, alkenyl, alkynyl, aryl, cycloalkyl, or aralkyl optionally substituted by alkyl, halo, nitro, cyano, CF₃, O-alkyl, or S-alkyl, and E' is -CO- or -SO₂-. Preferably, D' is alkyl, alkenyl, alkynyl, aryl, cycloalkyl, or aralkyl optionally substituted by alkyl, halo, or CF₃, and E' is -SO₂-. More preferably, D' is isobutyl and E' is -SO₂-.

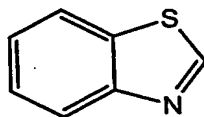
With regard to X', X' is selected from the group consisting of aryl and heteroaryl, which are substituted with one or more of the following groups: OR₃, OR₆, OR₇, OR₂ provided R₂ is not H or unsubstituted alkyl; alkyl substituted by R₃, R₅, R₆ provided R₅ is not halo; C2-C6 alkenyl, C2-C6 alkynyl, C3-C8 cycloalkyl, C5-C8 cycloalkenyl, and heterocyclo, which groups may be optionally substituted with one or more substituents selected from R₅; aryl or heteroaryl, wherein said aryl or heteroaryl may be optionally substituted with one or more groups selected from the group consisting of aryl, heteroaryl, R₂, R₃, R₄, and R₆; C3-C7 cycloalkyl substituted by R₂, R₃, R₅, R₆; provided R₂ is not H; CO₂H or R₇; provided R₈ is not H or unsubstituted alkyl; NR₈R₈, NR₇R₈, NR₇R₇; provided R₈ is not H or unsubstituted alkyl;

$\text{SO}_n\text{N}(\text{R}_8)_2$, $\text{SO}_n\text{NR}_7\text{R}_8$, SR_8 , $\text{S}(\text{O})_n\text{R}_8$, provided R_8 is not H or methyl; and n is 1 or 2.

X' may also be



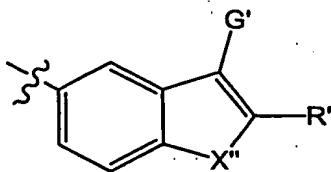
or



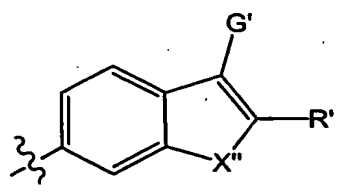
;

- 5 wherein said groups are substituted with one or more of the following groups:
 OR3, OR6, OR7, OR2 provided R_2 is not H or unsubstituted alkyl; alkyl
 substituted by R_3 , R_5 , R_6 provided R_5 is not halo; C2-C6 alkenyl, C2-C6
 alkynyl, C3-C8 cycloalkyl, C5-C8 cycloalkenyl, and heterocyclo, which
 groups may be optionally substituted with one or more substituents selected
 10 from R_5 ; aryl or heteroaryl, wherein said aryl or heteroaryl may be optionally
 substituted with one or more groups selected from the group consisting of aryl,
 heteroaryl, R_2 , R_3 , R_4 , and R_6 ; C3-C7 cycloalkyl substituted by R_2 , R_3 , R_5 ,
 R_6 ; provided R_2 is not H; CO_2H or R_7 ; provided R_8 is not H or unsubstituted
 alkyl; NR_8R_8 , NR_7R_8 , NR_7R_7 ; provided R_8 is not H or unsubstituted alkyl;
 -15 $\text{SO}_n\text{N}(\text{R}_8)_2$, $\text{SO}_n\text{NR}_7\text{R}_8$, SR_8 , $\text{S}(\text{O})_n\text{R}_8$, provided R_8 is not H or methyl; and n
 is 1 or 2.

X' may also be



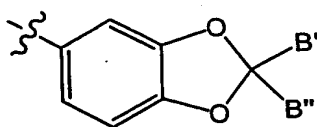
or



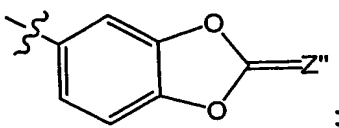
- 5 wherein G' and R' cannot both be H; G' and R' are each independently:
H or alkyl substituted by R3, R5, R6 provided R5 is not halo; C2-C6
alkenyl, C2-C6 alkynyl, C3-C8 cycloalkyl, C5-C8 cycloalkenyl, and
heterocyclo, which groups may be optionally substituted with one or
more substituents selected from the group consisting of -OR2,
10 C(O)N(R2)₂, S(O)_nN(R2)₂, CN, SR2, SO_nR2, COR2, CO₂R2 or
NR2C(O)R2, R5, and R7; aryl or heteroaryl, wherein said aryl or
heteroaryl may be optionally substituted with one or more groups
selected from the group consisting of aryl, heteroaryl, R2, R3, R4, and
R6; C3-C7 cycloalkyl substituted by R2, R3, R5, R6; provided R2 is
15 not H; CO₂H or R7 provided R2 is not H or unsubstituted alkyl;
SO_nN(R8)₂, SO_nNR7R8, SR8, S(O)_nR8, provided R8 is not H or
methyl; and n is 1 or 2; and X'' is selected from O or NR''; wherein R''
is H or alkyl optionally substituted by R3, R5, R6; C2-C6 alkenyl, C2-
C6 alkynyl, C3-C8 cycloalkyl, C5-C8 cycloalkenyl, and heterocyclo,
20 which groups may be optionally substituted with one or more
substituents selected from the group consisting of -OR2, C(O)N(R2)₂,

$S(O)_nN(R_2)_2$, CN, SR_2 , SO_nR_2 , COR_2 , CO_2R_2 or $NR_2C(O)R_2$, R_5 ,
 and R_7 ; aryl or heteroaryl, wherein said aryl or heteroaryl may be
 optionally substituted with one or more groups selected from the group
 consisting of aryl, heteroaryl, R_2 , R_3 , R_4 , and R_6 ; C3-C7 cycloalkyl
 optionally substituted by R_2 , R_3 , R_5 , R_6 ; R_7 ; NR_3R_3 , NR_6R_6 ,
 NR_7R_7 , NR_3R_6 , NR_6R_7 , NR_3R_7 , NR_2R_3 , NR_2R_6 , NR_2R_7 , NR_2R_2 ;
 $SO_nN(R_2)_2$, $SO_nN(R_3)_2$, $SO_nN(R_6)_2$, $SO_nN(R_7)_2$, $SO_nNR_2R_3$,
 $SO_nNR_2R_6$, $SO_nNR_2R_7$, $SO_nNR_3R_6$, $SO_nNR_3R_7$, $SO_nNR_6R_7$;
 $S(O)_mR_2$, $S(O)_mR_3$, $S(O)_mR_6$, provided R_2 is not H; and m is 0, 1 or 2.

X' may also be



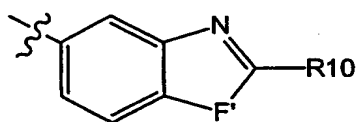
or



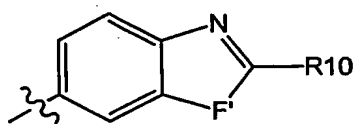
wherein B' and B'' cannot both be H or methyl; B' and B'' are independently: H
 or alkyl optionally substituted by R_3 , R_5 , R_6 ; C2-C6 alkenyl, C2-C6 alkynyl,
 C3-C8 cycloalkyl, C5-C8 cycloalkenyl, and heterocyclo, which groups may be
 optionally substituted with one or more substituents selected from the group
 consisting of $-OR_2$, $C(O)N(R_2)_2$, $S(O)_nN(R_2)_2$, CN, SR_2 , SO_nR_2 , COR_2 ,
 CO_2R_2 or $NR_2C(O)R_2$, R_5 , and R_7 ; aryl or heteroaryl, wherein said aryl or
 heteroaryl may be optionally substituted with one or more groups selected
 from the group consisting of aryl, heteroaryl, R_2 , R_3 , R_4 , and R_6 ; C3-C7
 cycloalkyl optionally substituted by R_2 , R_3 , R_5 , R_6 ; CO_2H or R_7 ; $SO_nN(R_2)_2$,

$\text{SO}_n\text{N}(\text{R}3)_2$, $\text{SO}_n\text{N}(\text{R}6)_2$, $\text{SO}_n\text{N}(\text{R}7)_2$, $\text{SO}_n\text{NR}2\text{R}3$, $\text{SO}_n\text{NR}2\text{R}6$, $\text{SO}_n\text{NR}2\text{R}7$,
 $\text{SO}_n\text{NR}3\text{R}6$, $\text{SO}_n\text{NR}3\text{R}7$, $\text{SO}_n\text{NR}6\text{R}7$; $\text{S}(\text{O})_m\text{R}2$, $\text{S}(\text{O})_m\text{R}3$, $\text{S}(\text{O})_m\text{R}6$;
 $\text{SO}_n\text{N}(\text{R}8)_2$, $\text{SO}_n\text{NR}7\text{R}8$, $\text{SR}8$, $\text{S}(\text{O})_n\text{R}8$, provided $\text{R}8$ is not H or methyl; and n
 is 1 or 2; and m is 0, 1 or 2; Z'' is O, $\text{NR}9$; $\text{R}9$ is alkyl optionally substituted by
 5 $\text{R}3$, $\text{R}5$, $\text{R}6$; C2-C6 alkenyl, C2-C6 alkynyl, C3-C8 cycloalkyl, C5-C8
 cycloalkenyl, and heterocyclo, which groups may be optionally substituted
 with one or more substituents selected from the group consisting of $-\text{OR}2$,
 $\text{C}(\text{O})\text{N}(\text{R}2)_2$, $\text{S}(\text{O})_n\text{N}(\text{R}2)_2$, CN , $\text{SR}2$, $\text{SO}_n\text{R}2$, $\text{COR}2$, $\text{CO}_2\text{R}2$ or $\text{NR}2\text{C}(\text{O})\text{R}2$,
 $\text{R}5$, and $\text{R}7$; aryl or heteroaryl, wherein said aryl or heteroaryl may be
 10 optionally substituted with one or more groups selected from the group
 consisting of aryl, heteroaryl, $\text{R}2$, $\text{R}3$, $\text{R}4$, and $\text{R}6$; C3-C7 cycloalkyl
 optionally substituted by $\text{R}2$, $\text{R}3$, $\text{R}5$, $\text{R}6$; CO_2H or $\text{R}7$; $\text{NR}3\text{R}3$, $\text{NR}6\text{R}6$,
 $\text{NR}7\text{R}7$, $\text{NR}3\text{R}6$, $\text{NR}6\text{R}7$, $\text{NR}3\text{R}7$, $\text{NR}2\text{R}3$, $\text{NR}2\text{R}6$, $\text{NR}2\text{R}7$, $\text{NR}2\text{R}2$;
 $\text{SO}_n\text{N}(\text{R}2)_2$, $\text{SO}_n\text{N}(\text{R}3)_2$, $\text{SO}_n\text{N}(\text{R}6)_2$, $\text{SO}_n\text{N}(\text{R}7)_2$, $\text{SO}_n\text{NR}2\text{R}3$, $\text{SO}_n\text{NR}2\text{R}6$,
 15 $\text{SO}_n\text{NR}2\text{R}7$, $\text{SO}_n\text{NR}3\text{R}6$, $\text{SO}_n\text{NR}3\text{R}7$, $\text{SO}_n\text{NR}6\text{R}7$; $\text{S}(\text{O})_m\text{R}2$, $\text{S}(\text{O})_m\text{R}3$,
 $\text{S}(\text{O})_m\text{R}6$, provided $\text{R}2$ is not H; and m is 0, 1 or 2.

X' may also be



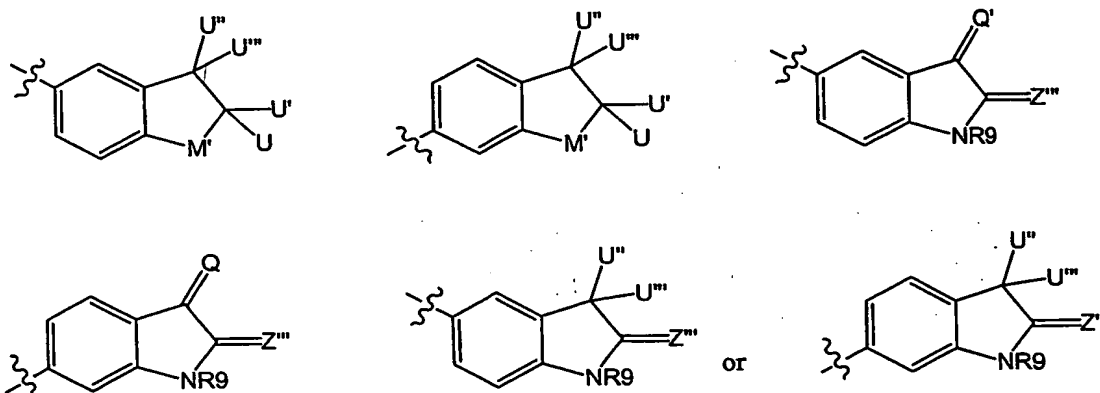
or



20 wherein $\text{R}10$ is alkyl substituted by $\text{R}3$, $\text{R}5$, $\text{R}6$ provided $\text{R}5$ is not halo; C2-
 C6 alkenyl, C2-C6 alkynyl, C3-C8 cycloalkyl, C5-C8 cycloalkenyl, and
 heterocyclo, which groups may be optionally substituted with one or more

substituents selected from the group consisting of $-OR_2$, $C(O)N(R_2)_2$, $S(O)_nN(R_2)_2$, CN , SR_2 , SO_nR_2 , COR_2 , CO_2R_2 or $NR_2C(O)R_2$, R_5 , and R_7 ; aryl or heteroaryl, wherein said aryl or heteroaryl may be optionally substituted with one or more groups selected from the group consisting of aryl, heteroaryl, R_2 , R_3 , R_4 , and R_6 ; C3-C7 cycloalkyl substituted by R_2 , R_3 , R_5 , R_6 ; provided R_2 is not H; R_7 provided Z is N, O, S and provided R_2 is not H or unsubstituted alkyl; and F' is O or S.

X' may also be



Wherein U and U' are each independently H or alkyl substituted by R_3 , R_5 , R_6 ; C2-C6 alkenyl, C2-C6 alkynyl, C3-C8 cycloalkyl, C5-C8 cycloalkenyl, and heterocyclo, which groups may be optionally substituted with one or more substituents selected from the group consisting of $-OR_2$, $C(O)N(R_2)_2$, $S(O)_nN(R_2)_2$, CN , SR_2 , SO_nR_2 , COR_2 , CO_2R_2 or $NR_2C(O)R_2$, R_5 , and R_7 ; aryl or heteroaryl, wherein said aryl or heteroaryl may be optionally substituted with one or more groups selected from the group consisting of aryl, heteroaryl, R_2 , R_3 , R_4 , and R_6 ; C3-C7 cycloalkyl substituted by R_2 , R_3 , R_5 , R_6 ; CO_2H , R_7 ; $SO_nN(R_8)_2$, $SO_nNR_7R_8$, SR_8 , $S(O)_nR_8$, provided R_8 is not H or methyl; and n is 1 or 2; $SO_nN(R_2)_2$, $SO_nN(R_3)_2$, $SO_nN(R_6)_2$, $SO_nN(R_7)_2$, $SO_nNR_2R_3$, $SO_nNR_2R_6$, $SO_nNR_2R_7$, $SO_nNR_3R_6$, $SO_nNR_3R_7$, $SO_nNR_6R_7$,

wherein $n = 1$ or 2 ; $S(O)_mR_2$, $S(O)_mR_3$, $S(O)_mR_6$, provided R_2 is not H; and n is 0 , 1 or 2 .

U'' and U''' are each independently H, OR3, OR6, OR7, OR2; alkyl substituted by R_3 , R_5 , R_6 ; C2-C6 alkenyl, C2-C6 alkynyl, C3-C8 cycloalkyl, C5-C8 cycloalkenyl, and heterocyclo, which groups may be optionally substituted with one or more substituents selected from the group consisting of -OR2, $C(O)N(R_2)_2$, $S(O)_nN(R_2)_2$, CN, SR2, SO_nR_2 , COR2, CO_2R_2 or $NR_2C(O)R_2$, R_5 , and R_7 ; aryl or heteroaryl, wherein said aryl or heteroaryl may be optionally substituted with one or more groups selected from the group consisting of aryl, heteroaryl, R_2 , R_3 , R_4 , and R_6 ; C3-C7 cycloalkyl substituted by R_2 , R_3 , R_5 , R_6 ; CO_2H or R_7 ; NR_3R_3 , NR_6R_6 , NR_7R_7 , NR_3R_6 , NR_6R_7 , NR_3R_7 , NR_2R_3 , NR_2R_6 , NR_2R_7 , NR_2R_2 ; $SO_nN(R_8)_2$, $SO_nNR_7R_8$, SR8, $S(O)_nR_8$, provided R_8 is not H or methyl; and n is 1 or 2 ; $SO_nN(R_2)_2$, $SO_nN(R_3)_2$, $SO_nN(R_6)_2$, $SO_nN(R_7)_2$, $SO_nNR_2R_3$, $SO_nNR_2R_6$, $SO_nNR_2R_7$, $SO_nNR_3R_6$, $SO_nNR_3R_7$, $SO_nNR_6R_7$; $S(O)_mR_2$, $S(O)_mR_3$, $S(O)_mR_6$, provided R_2 is not H; and m is 0 , 1 or 2 ; U and U' cannot both be H unless one of U'' and U''' is not H; U'' and U''' cannot both be H unless one of U and U' is not H; M' is O, NR9, or NH, except where R_9 is CO_2H ; Z''' is O or NR9; Q' is O, NR9, or $CU''U'''$.

R_9 is alkyl optionally substituted by R_3 , R_5 , R_6 ; C2-C6 alkenyl, C2-C6 alkynyl, C3-C8 cycloalkyl, C5-C8 cycloalkenyl, and heterocyclo, which groups may be optionally substituted with one or more substituents selected from the group consisting of -OR2, $C(O)N(R_2)_2$, $S(O)_nN(R_2)_2$, CN, SR2, SO_nR_2 , COR2, CO_2R_2 or $NR_2C(O)R_2$, R_5 , and R_7 ; aryl or heteroaryl, wherein said aryl or heteroaryl may be optionally substituted with one or more groups selected from the group consisting of aryl, heteroaryl, R_2 , R_3 , R_4 , and R_6 ; C3-C7 cycloalkyl optionally substituted by R_2 , R_3 , R_5 , R_6 ; CO_2H or R_7 ; NR_3R_3 , NR_6R_6 , NR_7R_7 , NR_3R_6 , NR_6R_7 , NR_3R_7 , NR_2R_3 , NR_2R_6 ,

NR₂R₇, NR₂R₂; SO_nN(R₈)₂, SO_nNR₇R₈, SR₈, S(O)_nR₈, provided R₈ is not H or methyl; and n is 1 or 2; SO_nN(R₂)₂, SO_nN(R₃)₂, SO_nN(R₆)₂, SO_nN(R₇)₂, SO_nNR₂R₃, SO_nNR₂R₆, SO_nNR₂R₇, SO_nNR₃R₆, SO_nNR₃R₇, SO_nNR₆R₇; S(O)_mR₂, S(O)_mR₃, S(O)_mR₆, provided R₂ is not H; and m is 0, 1 or 2.

- 5 Preferably, R is H or alkyl, aryl, alkenyl, alkynyl, cycloalkyl, cycloalkenyl, heterocyclo, heteroaryl; optionally substituted by halo, hydroxy, alkoxy, aryloxy, cycloalkoxy, heteroaryloxy, cyano, nitro, alkylthio, arylthio, cycloalkylthio, amino, or mono- or dialkylamino, mono- or diarylamino, mono- or di-cycloalkylamino, mono- or di-heteroarylamino, alkanoyl, cycloalkanoyl, aroyl, heteroaroyl, carboxamido, mono- or dialkylcarboxamido, 10 mono- or diarylcarboxamido, sulfonamido, mono- or dialkylsulfonamido, mono- or diarylsulfonamido, alkylsulfinyl, alkylsulfonyl, arylsulfinyl, arylsulfonyl, cycloalkylsulfinyl, cycloalkylsulfonyl, heteroarylsulfinyl, heteroarylsulfonyl.
- 15 Preferably, R₂ is H or C1-C6 alkyl; optionally substituted by C2-C6 alkenyl, C2-C6 alkynyl, C3-C8 cycloalkyl, C5-C8 cycloalkenyl, heterocyclo; which groups may be optionally substituted with one or more substituents selected from the group consisting of halo, OR, ROH, R-halo, NO₂, CN, CO_nR, CON(R)₂, C(S)R, C(S)N(R)₂, SO_nN(R)₂, SR, SO_nR, N(R)₂, N(R)CO_nR, 20 NRS(O)_nR, NRC[=N(R)]N(R)₂, N(R)N(R)CO_nR, NRPO_nN(R)₂, NRPO_nOR, oxo, =N-OR, =N-N(R)₂, =NR, =NNRC(O)N(R)₂, =NNRCO_nR, =NNRS(O)_nN(R)₂, or =NNRS(O)_n(R); or R₂ is C1-C6 alkyl; substituted by aryl or heteroaryl; which groups may be optionally substituted with one or more substituents selected from the group consisting of halo, OR, ROH, R-halo, NO₂, CN, CO_nR, CON(R)₂, C(S)R, C(S)N(R)₂, SO_nN(R)₂, SR, SO_nR, 25 N(R)₂, N(R)CO_nR, NRS(O)_nR, NRC[=N(R)]N(R)₂, N(R)N(R)CO_nR, NRPO_nN(R)₂, NRPO_nOR; or R₂ is C1-C6 alkyl; optionally substituted by halo, OR, ROH, R-halo, NO₂, CN, CO_nR, CON(R)₂, C(S)R, C(S)N(R)₂, SO_nN(R)₂,

SR, SO_nR , N(R)_2 , $\text{N(R)CO}_n\text{R}$, $\text{NRS(O)}_n\text{R}$; NRC[=N(R)]N(R)_2 ,
 $\text{N(R)N(R)CO}_n\text{R}$, $\text{NRPO}_n\text{N(R)}_2$, NRPO_nOR , oxo, $=\text{N-OR}$, $=\text{N-N(R)}_2$, $=\text{NR}$,
 $=\text{NNRC(O)N(R)}_2$, $=\text{NNRCONR}$, $=\text{NNRS(O)}_n\text{N(R)}_2$, or $=\text{NNRS(O)}_n\text{(R)}$.

Preferably, R3 is C2-C6 alkenyl, C2-C6 alkynyl, C3-C8 cycloalkyl, C5-C8
 5 cycloalkenyl, or heterocyclo; which groups may be optionally substituted with
 one or more substituents selected from the group consisting of halo, OR2, R2-
 OH, R2-halo, NO_2 , CN, CO_nR_2 , C(O)N(R)_2 , C(O)N(R)N(R)_2 , C(S)R_2 ,
 C(S)N(R)_2 , $\text{S(O)}_n\text{N(R)}_2$, SR_2 , SO_nR_2 , N(R)_2 , $\text{N(R)}_2\text{CO}_n\text{R}_2$, $\text{NR}_2\text{S(O)}_n\text{R}_2$,
 $\text{NR}_2\text{C[=N(R)}_2\text{)]N(R)}_2$, $\text{N(R)}_2\text{N(R)}_2\text{CO}_n\text{R}_2$, $\text{NR}_2\text{PO}_n\text{N(R)}_2$, $\text{NR}_2\text{PO}_n\text{OR}_2$,
 10 oxo, $=\text{N-OR}_2$, $=\text{N-N(R)}_2$, $=\text{NR}_2$, $=\text{NNRC(O)N(R)}_2$, $=\text{NNR}_2\text{C(O)}_n\text{R}_2$,
 $=\text{NNR}_2\text{S(O)}_n\text{N(R)}_2$, or $=\text{NNR}_2\text{S(O)}_n\text{(R)}_2$.

Preferably, R4 is halo, OR8, R2-OH, R3-OH, R2-halo, R3-halo, NO_2 , CN,
 CO_nR_8 , CO_nR_8 , CON(R)_8 , C(O)N(R)N(R)_2 , C(S)R_8 , C(S)N(R)_2 ,
 $\text{SO}_n\text{N(R)}_2$, SR_8 , SO_nR_8 , N(R)_2 , $\text{N(R)}_2\text{CO}_n\text{R}_8$, $\text{NR}_8\text{S(O)}_n\text{R}_8$,
 15 $\text{NR}_8\text{C[=N(R)}_8\text{)]N(R)}_2$, $\text{N(R)}_8\text{N(R)}_2\text{CO}_n\text{R}_8$, $\text{NR}_8\text{PO}_n\text{N(R)}_2$, $\text{NR}_8\text{PO}_n\text{OR}_8$,
 OC(O)R_2 , OC(S)R_8 , OC(O)N(R)_2 , OC(S)N(R)_2 , $\text{OPO}_n\text{(R)}_2$.

Preferably, R5 is OR8, N(R)_2 , NHOH, $\text{N(R)}_2\text{COR}_8$, $\text{NR}_8\text{S(O)}_n\text{R}_8$,
 $\text{NR}_8\text{C[=N(R)}_8\text{)]N(R)}_2$, $\text{N(R)}_8\text{N(R)}_2\text{C(O)R}_8$, $\text{NR}_8\text{PO}_n\text{N(R)}_2$, $\text{NR}_8\text{PO}_n\text{OR}_8$,
 R2OH, R3-OH, R2-halo, R3-halo, CN, CO_nR_8 ; provided that when $n = 2$, R8
 20 is not H; CON(R)_8 , C(O)N(R)N(R)_2 , $\text{C(S)}_n\text{R}_8$, C(S)N(R)_2 , $\text{S(O)}_n\text{R}_8$,
 $\text{SO}_n\text{N(R)}_2$, halo, NO_2 , SR_8 , oxo, $=\text{N-OH}$, $=\text{N-OR}_8$, $=\text{N-N(R)}_2$, $=\text{NR}_8$,
 $=\text{NNR}_8\text{C(O)N(R)}_2$, $=\text{NNR}_8\text{C(O)}_n\text{R}_8$, $=\text{NNR}_8\text{S(O)}_n\text{N(R)}_2$, or
 $=\text{NNR}_8\text{S(O)}_n\text{(R)}_8$, or R3.

Preferably, R6 is aryl or heteroaryl, wherein said aryl or heteroaryl may be
 25 optionally substituted with one or more groups selected from aryl, heteroaryl,
 R2, R3, halo, OR2, R2OH, R2-halo, NO_2 , CN, CO_nR_2 , C(O)N(R)_2 ,
 C(O)N(R)N(R)_2 , C(S)R_2 , C(S)N(R)_2 , $\text{S(O)}_n\text{N(R)}_2$, SR_2 , SO_nR_2 , N(R)_2 ,

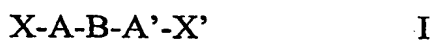
$N(R_2)CO_nR_2$, $NR_2S(O)_nR_2$, $NR_2C[=N(R_2)]N(R_2)_2$, $N(R_2)N(R_2)CO_nR_2$,
 $NR_2PO_nN(R_2)_2$, $NR_2PO_nOR_2$, $OC(O)R_2$, $OC(S)R_2$, $OC(O)N(R_2)_2$,
 $OC(S)N(R_2)_2$, $OPO_n(R_2)_2$.

Preferably, R_7 is $C(O)_nR_8$; provided that when $n = 2$; R_8 is not H; $C(S)R_8$,
 $C(O)N(R_8)_2$, $C(S)N(R_8)_2$, $S(O)_nR_8$, $S(O)_nN(R_8)_2$.

Preferably, R_8 is R_2 , R_3 , or R_6 ; and Z is N, O, or S.

Figure 7 describes a set of three-dimensionally-conserved substructures of an HIV protease substrate binding site and the substructure of atoms of an inhibitor interacting with the conserved substructure of the protease. The substructures are defined by the set of atomic coordinates, referred to an orthogonal system of coordinates shown below. The skilled artisan will recognize that any set of coordinates derived by applying arbitrary rotations and translations to the set of atomic coordinates in this table will be equivalent to the coordinates shown. The values of the coordinates (x,y,z) of the atoms defining the substructure are affected by a standard error σ . Therefore (x,y,z) values for each atom are those defined in the intervals $(x-\sigma, x+\sigma)$ for coordinate x , $(y-\sigma, y+\sigma)$ for coordinate y , and $(z-\sigma, z+\sigma)$ for coordinate z .

Accordingly, the invention provides an HIV protease inhibitor having the formula I:



wherein X is a moiety comprising first and second hydrogen bond acceptor atoms $H_{A1}:X$ and $H_{A2}:X$, wherein $H_{A1}:X$ forms a hydrogen bond with N29 of HIV protease and $H_{A2}:X$ forms a hydrogen bond with N30 of HIV protease at the relative positions designated in Table 8;

wherein A is an optionally substituted linker moiety comprising a linear chain of 2-6 atoms, wherein A comprises a hydrogen bond acceptor atom $H_A:A$, and a hydrogen bond donor atom $H_D:A$, and wherein $H_A:A$ forms a hydrogen bond with solvated water³⁰¹ of said protease at a relative position designated by O301, and $H_D:A$ forms a hydrogen bond with the backbone CO atom of residue 27 of said protease at a relative position designated by O27;

wherein B comprises a hydrogen bond donor or acceptor atom $H_{D/A}:B$, wherein $H_{D/A}:B$ forms a hydrogen bond with either or both carboxylate side chain oxygens of Asp25 and Asp 125 of said protease at relative positions designated by OD1 25, OD2 25, OD1 125, and OD2 125;

wherein A' is an optionally substituted linker moiety comprising a linear chain of 2-6 atoms, comprising a hydrogen bond acceptor atom $H_A:A'$, wherein $H_A:A'$ forms a hydrogen bond with solvated water³⁰¹ of said protease at a relative position designated by O301; and

wherein X' is a moiety comprising a hydrogen bond acceptor atom $H_A:X'$, wherein $H_A:X'$ forms a hydrogen bond with backbone NH atoms of residues 129 and/or 130 of said protease at relative positions designated by N129 and/or N130.

The compound of Formula I specifically can not be any of the compounds described in *J. Med. Chem.* 39:3278-3290 (1996), in *Bioorg. Med. Chem. Lett.* 8:687-690 (1998), or *Bioorg. Med. Chem. Lett.* 8:979-982 (1998), which compounds are specifically disclaimed herein. The HIV inhibitors described in the following documents also are specifically disclaimed: EP00/9917, WO00/76961, WO99/65870, WO02/083657, WO02/081478, WO02/092595, WO99/67417, and U.S. Patents Nos. 5,990,155 and 6,319,946, the contents of which are incorporated herein by reference.

In another preferred embodiment, the invention also provides compounds of the instant invention bound in a complex with wild type or drug resistant mutant forms of HIV-1 protease.

5 In another preferred embodiment, the invention also provides a composition comprising an inhibitor according to the instant invention and a pharmaceutically acceptable additive, excipient, or diluent.

In another preferred embodiment, the invention also provides an pharmaceutical composition comprising an inhibitor according to the instant invention and another antiretroviral agent.

10 In another preferred embodiment, the invention also provides a composition comprising an inhibitor according to the instant invention and a second HIV inhibitor;

In another preferred embodiment, the invention also provides an inhibitor according to the instant invention and an additional HIV protease inhibitor.

15 In another preferred embodiment, the invention also provides an inhibitor according to the instant invention and an HIV reverse transcriptase inhibitor.

20 In another preferred embodiment, the invention also provides a method of treating a patient suffering from HIV infection, comprising administering to said patient a composition according to the instant invention. Preferably, the patient is suffering from a multi-drug resistant HIV infection.

25 The term "alkyl", alone or in combination with any other term, refers to a straight-chain or branch-chain saturated aliphatic hydrocarbon radical containing the specified number of carbon atoms, or where no number is specified, preferably from 1 to about 15 and more preferably from 1 to about 10 carbon atoms. Examples of alkyl radicals include, but are not limited to,

methyl, ethyl, n-propyl, isopropyl, n-butyl, isobutyl, sec-butyl, tert-butyl, pentyl, isoamyl, n-hexyl and the like.

The term "alkenyl", alone or in combination with any other term, refers to a straight-chain or branched-chain mono- or poly-unsaturated aliphatic hydrocarbon radical containing the specified number of carbon atoms, or where no number is specified, preferably from 2-10 carbon atoms and more preferably, from 2-6 carbon atoms. Examples of alkenyl radicals include, but are not limited to, ethenyl, E- and Z-propenyl, isopropenyl, E- and Z-butenyl, E- and Z-isobutenyl, E- and Z-pentenyl, E- and Z-hexenyl, E,E-, E,Z-, Z,E- and Z,Z-hexadienyl and the like.

The term "alkynyl," alone or in combination with any other term, refers to a straight-chain or branched-chain hydrocarbon radical having one or more triple bonds containing the specified number of carbon atoms, or where no number is specified, preferably from 2 to about 10 carbon atoms. Examples of alkynyl radicals include, but are not limited to, ethynyl, propynyl, propargyl, butynyl, pentynyl and the like.

The term "alkoxy" refers to an alkyl ether radical, wherein the term "alkyl" is defined above. Examples of suitable alkyl ether radicals include, but are not limited to, methoxy, ethoxy, n-propoxy, isopropoxy, n-butoxy, isobutoxy, sec-butoxy, tert-butoxy and the like.

The term "aryl," alone or in combination with any other term, refers to a carbocyclic aromatic radical (such as phenyl or naphthyl) containing the specified number of carbon atoms, preferably from 6-15 carbon atoms, and more preferably from 6-10 carbon atoms, optionally substituted with one or more substituents selected from alkyl, alkoxy, (for example methoxy), nitro, halogen, (for example chloro), amino, carboxylate and hydroxy. Examples of aryl radicals include, but are not limited to phenyl, p-tolyl, 4-hydroxyphenyl,

1-naphthyl, 2-naphthyl, indenyl, indanyl, azulenyl, fluorenyl, anthracenyl and the like.

5 The term "aralkyl", alone or in combination, means an alkyl radical as defined above in which one hydrogen atom is phenyl, benzyl, 2-phenylethyl and the like.

The term "aralkoxy carbonyl", alone or in combination, means a radical of the formula $-C(O)-O\text{-aralkyl}$ in which the term "aralkyl" has the significance given above. An example of an aralkoxycarbonyl radical is benzyloxycarbonyl.

10 The term "aryloxy", alone or in combination, means a radical of the formula aryl-O- in which the term "aryl" has the significance given above.

The term "alkanoyl", alone or in combination, means an acyl radical derived from an alkanecarboxylic acid, examples of which include acetyl, propionyl, butyryl, valeryl, 4-methylvaleryl, and the like.

15 The term "aryloxyalkanoyl" means an acyl radical of the formula aryl-O-alkanoyl wherein aryl and alkanoyl have the significance given above.

20 The term "aralkanoyl" means an acyl radical derived from an aryl-substituted alkanecarboxylic acid such as phenylacetyl, 3-phenylpropionyl (hydrocinnamoyl), 4-phenylbutyryl, (2-naphthyl)acetyl, 4-chlorohydrocinnamoyl, 4-aminohydrocinnamoyl, 4-phenylbutyryl, (1-naphthyl)acetyl, 4-chlorohydrocinnamoyl, 4-aminohydrocinnamoyl, 4-methoxyhydrocinnamoyl, and the like.

25 The term "aroyl" means an acyl radical derived from an aromatic carboxylic acid. Examples of such radicals include aromatic carboxylic acids, an optionally substituted benzoic or naphthoic acid such as benzoyl, 4-

chlorobenzoyl, 4-carboxybenzoyl, 4-benzyloxycarbonyl)benzoyl, 1-naphthoyl, 2-naphthoyl, 6-carboxy-2-naphthoyl, 6-(benzyloxycarbonyl)-2-naphthoyl, 3-benzyloxy-2-naphthoyl, 3-hydroxy-2-naphthoyl, 3-(benzyloxyformamido)-2-naphthoyl, and the like.

5 The term "aminocarbonyl" alone or in combination, means an amino-substituted carbonyl (carbamoyl) group derived from an amino-substituted carboxylic acid wherein the amino group can be a primary, secondary or tertiary amino group continuing substituents selected from hydrogen, alkyl, aryl, aralkyl, cycloalkyl, cycloalkylalkyl radicals and the like.

10 The term "aminoalkanoyl" means an acyl radical derived from an amino substituted alkanecarboxylic acid wherein the amino group can be a primary, secondary or tertiary amino group containing substituents selected from the group consisting of hydrogen, cycloalkyl, cycloalkylalkyl radicals and the like, examples of which include N,N-dimethylaminoacetyl and N-
15 benzylaminoacetyl.

The term "carbocycle" refers to a non-aromatic stable 3- to 8-membered carbon ring which may be saturated, mono-unsaturated or poly-unsaturated. The carbocycle may be attached at any endocyclic carbon atom which results in a stable structure. Preferred carbocycles have 5-7 carbons.

20 The term "cycloalkyl", alone or in combination, means an alkyl radical which contains from about 3 to about 8 carbon atoms and is cyclic. Examples of such cycloalkyl radicals include cyclopropyl, cyclobutyl, cyclopentyl, cyclohexyl and the like.

The term "cycloalkylalkyl" means an alkyl radical as defined above which is
25 substituted by a cycloalkyl radical containing from about 3 to about 8, preferably from about 3 to about 6, carbon atoms.

The term "cycloalkylcarbonyl" means an acyl group derived from a monocyclic or bridged cycloalkanecarboxylic acid such as cyclopropanecarbonyl, cyclohexanecarbonyl, adamantanecarbonyl, and the like, or from a benz-fused monocyclic cycloalkanecarboxylic acid which is optionally substituted by, for example, alkanoylamino, such as 1,2,3,4-tetrahydro-2-naphthoyl, 2-acetamido-1,2,3,4-tetrahydro-2-naphthoyl.

The term "cycloalkylalkoxycarbonyl" means an acyl group derived from a cycloalkylalkoxycarboxylic acid of the formula cycloalkylalkyl-O-COOH wherein cycloalkylalkyl has the significance given above.

The term "heterocyclyl" or "heterocycle" refers to a stable 3-7 membered monocyclic heterocyclic ring or 8-11 membered bicyclic heterocyclic ring which is either saturated or partially unsaturated, and which may be optionally benzofused if monocyclic and which is optionally substituted on one or more carbon atoms by halogen alkyl, alkoxy, oxo, and the like, and/or on a secondary nitrogen atom (i.e., -NH-) by alkyl, aralkoxycarbonyl, alkanoyl, phenyl or phenylalkyl or on a tertiary nitrogen atom (i.e., +N-) by oxido and which is attached via a carbon atom. Each heterocycle consists of one or more carbon atoms and from one to four heteroatoms selected from the group consisting of nitrogen, oxygen and sulfur. As used herein, the terms "nitrogen and sulfur heteroatoms" include any oxidized form of nitrogen and sulfur, and the quaternized form of any basic nitrogen. A heterocyclyl radical may be attached at any endocyclic carbon or heteroatom which results in the creation of a stable structure. Preferred heterocycles include 5-7 membered monocyclic heterocycles and 8-10 membered bicyclic heterocycles. Examples of such groups imidazolinoyl, imidazolidinyl, indazolinoyl, perhydropyridazyl, pyrrolinyl, pyrrolidinyl, piperidinyl, pyrazolinyl, piperazinyl, morpholinyl, thiamorpholinyl, thiazolidinyl, thiamorpholinyl sulfone, oxopiperidinyl, oxopyrrolidinyl, oxoazepinyl, tetrahydropyranyl, tetrahydrofuranyl, dioxolyl,

dioxinyl, benzodioxolyl, dithiolyl, tetrahydrothienyl, sulfolanyl, dioxanyl, dioxolanyl, tetrahydrofurodihydrofuranyl, tetrahydropyranodihydrofuranyl, dihydropyranyl, tetrahydrofurofuranyl and tetrahydropyranofuranyl.

5 The term heteroaryl refers to a stable 5-6 membered monocyclic or 8-11 membered bicyclic aromatic heterocycles where heterocycles is as defined above. Examples of such groups include imidazolyl, quinolyl, isoquinolyl, indolyl, indazolyl, pyridazyl, pyridyl, pyrrolyl, pyrazolyl, pyrazinyl, quinoxolyl, pyranyl, pyrimidinyl, furyl, thienyl, triazolyl, thiazolyl, carbolinyl, tetrazolyl, benzofuranoyl, thiamorpholinyl sulfone, oxazolyl, benzoxazolyl, 10 benzimidazolyl, benzthiazolyl, oxopiperidinyl, oxopyrrolidinyl, oxoazepinyl, azepinyl, isoxazolyl, isothiazolyl, furazanyl, thiazolyl, thiadiazoyl, oxathiolyl.

The term "heterocyclylalkanoyl" is an acyl radical derived from a heterocyclyl-substituted alkane carboxylic acid wherein heterocyclyl has the significance given above.

15 The term "heterocyclyloxycarbonyl" means an acyl group derived from heterocyclyl-O-COOH wherein heterocyclyl is as defined above.

The term "heterocyclylalkoxycarbonyl" means an acyl radical derived from heterocyclyl-substituted alkane-O-COOH wherein heterocyclyl has the significance given above.

20 The term "heteroaryloxycarbonyl" means an acyl radical derived from a carboxylic acid represented by heteroaryl-O-COOH wherein heteroaryl has the significance given above.

The term "halogen" means fluorine, chlorine, bromine or iodine.

25 The term haloalkyl means an alkyl with one or more of its hydrogens replaced by halogens.

The term "thioalkyl" means an alkyl radical having at least one sulfur atom, wherein alkyl has the significance given above. An example of a thioalkyl is CH_3SCH_3 . The corresponding sulfoxide and sulfone of this thioalkyl $\text{CH}_3\text{S(O)CH}_3$ and $\text{CH}_3\text{S(O)}_2\text{CH}_3$ respectively. Unless expressly stated to the contrary, the terms "-SO₂-" and "-S(O)₂-" as used herein refer to a sulfone or sulfone derivative (i.e., both appended groups linked to the S), and not a sulfinic ester.

The term "substituted", whether preceded by the term "optionally" or not, and substitutions contained in formulas of this invention, refer to the replacement of one or more hydrogen radicals in a given structure with the radical of a specified substituent. When more than one position in a given structure may be substituted with more than one substituent selected from a specified group, the substituents may be either the same or different at every position (for example, the moiety $-\text{N}(\text{R}_2)(\text{R}_2)$). Typically, when a structure may be optionally substituted, 0-3 substitutions are preferred, and 0-1 substitutions is more preferred. Most preferred substituents are those which enhance protease inhibitory activity or intracellular antiviral activity in permissive mammalian cells or immortalized mammalian cell lines, or which enhance deliverability by enhancing solubility characteristics or enhancing pharmacokinetic or pharmacodynamic profiles as compared to the unsubstituted compound. Combinations of substituents and variables envisioned by this invention are only those that result in the formation of stable compounds. The term "stable", as used herein, refers to compounds which possess stability sufficient to allow manufacture and administration to a mammal by methods known in the art. Typically, such compounds are stable at a temperature of 40 °C. or less, in the absence of moisture or other chemically reactive conditions, for at least a week.

This invention also envisions the quaternization of any basic nitrogen-containing groups of the compounds disclosed herein. The basic nitrogen can be quaternized with any agents known to those of ordinary skill in the art including, for example, lower alkyl halides, such as methyl, ethyl, propyl and butyl chloride, bromides and iodides; dialkyl sulfates including dimethyl, diethyl, dibutyl and diamyl sulfates; long chain halides such as decyl, lauryl, myristyl and stearyl chlorides, bromides and iodides; and aralkyl halides including benzyl and phenethyl bromides. Water or oil-soluble or dispersible products may be obtained by such quaternization.

As used herein, the compounds of this invention, including the compounds of formula I are defined to include pharmaceutically acceptable derivatives or prodrugs thereof. A "pharmaceutically acceptable derivative or prodrug" means any pharmaceutically acceptable salt, ester, salt of an ester, or other derivative of a compound of this invention which, upon administration to a recipient, is capable of providing (directly or indirectly) a compound of this invention or an inhibitorily active metabolite or residue thereof. Particularly favored derivatives and prodrugs are those that increase the bioavailability of the compounds of this invention when such compounds are administered to a mammal (e.g., by allowing an orally administered compound to be more readily absorbed into the blood) or which enhance delivery of the parent compound to a biological compartment (e.g., the brain or lymphatic system) relative to the parent species.

Salts derived from appropriate bases include alkali metal (e.g., sodium), alkaline earth metal (e.g., magnesium), ammonium and N-(C₁₋₄alkyl)₄⁺ salts.

The compounds of this invention contain one or more asymmetric carbon atoms and thus occur as racemates and racemic mixtures, single enantiomers, diastereomeric mixtures and individual diastereomers. All such isomeric

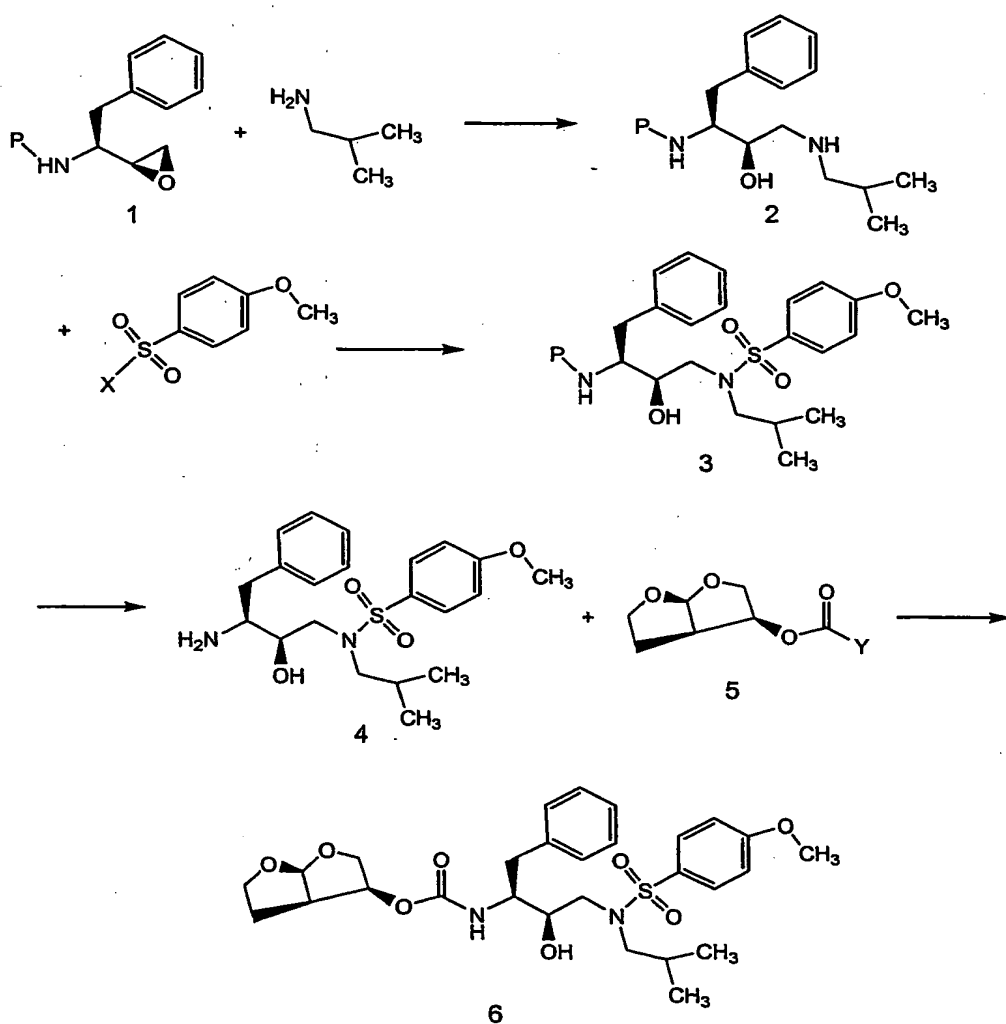
forms of these compounds are expressly included in the present invention. Each stereogenic carbon may be of the R or S configuration. Although the specific compounds exemplified in this application may be depicted in a particular stereochemical configuration, compounds having either the opposite stereochemistry at any given chiral center or mixtures thereof are also envisioned.

The compounds of the present invention may be used in the form of pharmaceutically acceptable salts derived from inorganic or organic acids. Included among such acid salts, for example, are the following: acetate, adipate, alginate, aspartate, benzoate, benzenesulfonate, bisulfate, butyrate, citrate, camphorate, camphorsulfonate, cyclopentanepropionate, digluconate, dodecylsulfate, ethanesulfonate, fumarate, glucoheptanoate, glycerophosphate, hemisulfate, heptanoate, hexanoate, hydrochloride, hydrobromide, hydroiodide, 2-hydroxyethanesulfonate, lactate, maleate, methanesulfonate, 2-naphthalenesulfonate, nicotinate, oxalate, pamoate, pectinate, persulfate, 3-phenylpropionate, picrate, pivalate, propionate, succinate, tartrate, thiocyanate, tosylate and undecanoate.

The instant compounds may be easily prepared according to those synthetic methods set forth in U.S. Patent No. 6,319,946 to Hale et al., the disclosure of which is incorporated herein by reference in its entirety. These methods will be evident to those of ordinary skill in the art.

The following scheme may be followed to synthesize the instant compounds where the X substituent can be being varied. In this scheme P is a standard amine protecting group such as Boc or Cbz. The amine is reacted with the epoxide as described previously (*J.Med.Chem.* 36, 288-291 (93)). The resulting aminoalcohol is reacted with an activated sulfonic acid derivative where X is a leaving group such as halo, an activated alcohol, or a sulfonate.

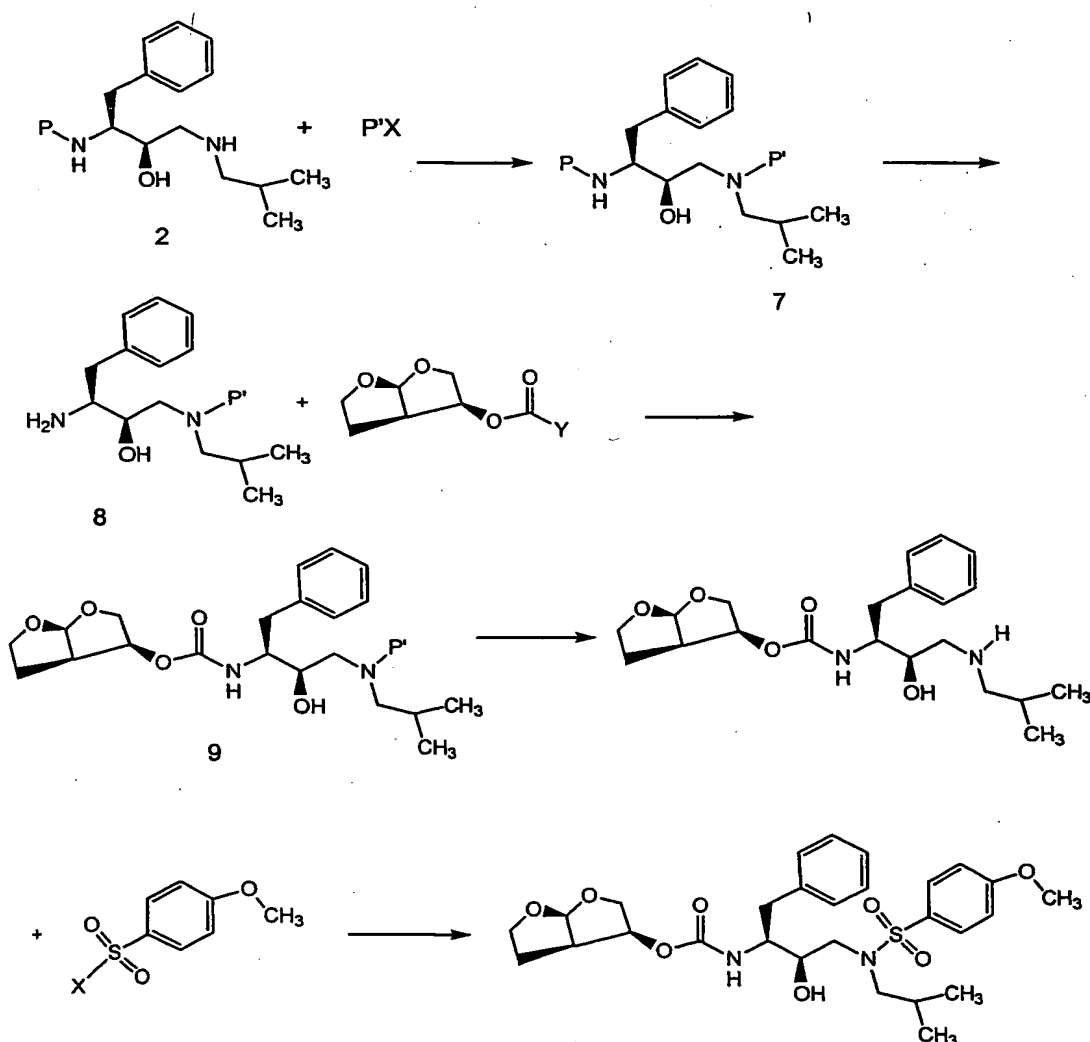
The protecting group is then removed from 3 and the resulting amino alcohol 4 is reacted with an activated oxycarbonyl derivative 5 (where Y is a leaving group such as halo or an activated alcohol) to give target compound 6. Compound 5 is generated from the corresponding alcohol by reacting with an acid chloride or an activated ester under standard conditions and is either isolated or used *in situ*.



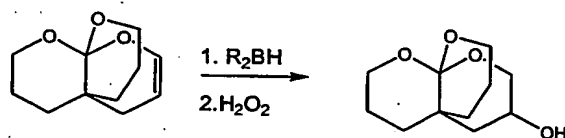
A diprotected amino epoxide such as (N,N-dibenzyl) may also be used as can an azido group that will eventually be reduced to an amine. In certain

examples the activated sulfonyl derivative may be reacted with the amine and the resulting sulfonamide reacted with the epoxide under basic conditions.

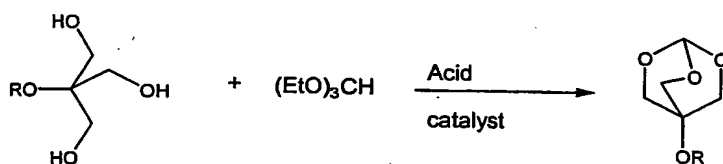
A second representative synthesis can be used when exploring variations of X'. Here instead of being sulfonylated, amino alcohol 2 can be N-protected by a group that is not removed by removing P, for example P is Boc and P' is Carbobenzyloxy. The di-protected 7 is then deprotected to give 8 which is reacted as above to give 9. Following deprotection of 9 various X' groups may be introduced via the activated sulfonyl derivatives in a similar fashion as described above.



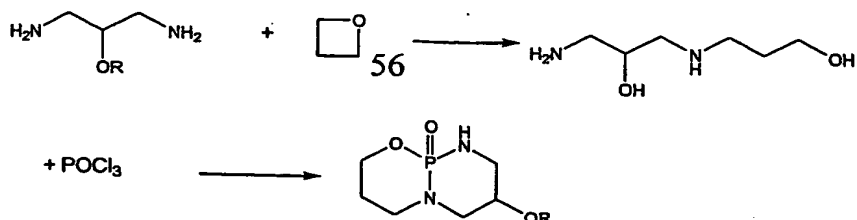
An example of a synthesis of X with a third fused ring is shown below. This olefinic tricyclic system has already been described by *McElvain, et al. JACS* 77, 5601 (1955). Anti-Markownikov addition of water across the double bond using standard conditions can provide the target alcohol. It is noteworthy that these authors showed that the unsubstituted tricyclic system had unusual acid stability, which may help prolong the activity of our target compounds.



The synthesis of a bicyclo[2.2.0] system can proceed in a similar fashion as has been described *Padias, et al. J.O.C. 52, 5305 (1987)* for a homologous analog. R can either be H or a protecting group such as benzyl that can subsequently be removed under standard conditions. Protic (e.g. toluenesulfonic) or Lewis (e.g. scandium triflate) acids can be used for the condensation.



The synthesis of a representative phosphorus containing bicycle described herein. Similar chemistry has been described by *Arnold, et al. In Ang. Chem* 70, 539 (1958) and *Dankiewicz, et al. in JACS* 101, 7712 (1979). The R group in the target shown may either be H or a protecting group such as benzyl that can subsequently be removed.



Other pharmaceutically acceptable salts include a salt with an inorganic base, organic base, inorganic acid, organic acid, or basic or acidic amino acid. Inorganic bases which form the instant pharmaceutically acceptable salts
5 include alkali metals such as sodium or potassium, alkali earth metals such as calcium and magnesium or aluminum, and ammonia. Organic bases which form the instant pharmaceutically acceptable salts include trimethylamine, triethylamine, pyridine, picoline, ethanolamine, diethanolamine, triethanolamine, dicyclohexylamine. Inorganic acids which form the instant
10 pharmaceutically acceptable salts include hydrochloric acid, hydroboric acid, nitric acid, sulfuric acid, and phosphoric acid. Organic acids appropriate to form the salt include formic acid, acetic acid, trifluoroacetic acid, fumaric acid, oxalic acid, tartaric acid, maleic acid, citric acid, succinic acid, malic acid, methanesulfonic acid, benzenesulfonic acid, and p-toluenesulfonic acid. Basic
15 amino acids to form the salt include arginine, lysine and ornithine. Acidic amino acids to form the salt include aspartic acid and glutamic acid.

The instant invention also contemplates compositions which can be administered orally or non-orally in the form of, for example, granules, powders, tablets, capsules, syrup, suppositories, injections, emulsions, elixir,
20 suspensions or solutions, by mixing these effective components, individually or simultaneously, with pharmaceutically acceptable carriers, excipients, binders, diluents or the like.

The compounds of the present invention are useful in the treatment of individuals infected by HIV and for the prophylaxis of these individuals. The
25 present invention may be useful in the treatment of mammals infected with viruses whose existence is mediated by, or depends upon, the protease enzyme. Conditions which may be prevented or treated with the compounds of

the present invention, especially conditions associated with HIV and other pathogenic retroviruses, include AIDS, AIDS-related complex (ARC), progressive generalized lymphadenopathy (POL), as well as chronic CNS diseases caused by retroviruses, such as, for example HIV-mediated dementia and multiple sclerosis.

As a solid formulation for oral administration, the instant composition may be in the form of powders, granules, tablets, pills and capsules. In these cases, the instant compounds can be mixed with at least one additive, for example, sucrose, lactose, cellulose sugar, mannitol, maltitol, dextran, starch, agar, alginates, chitins, chitosans, pectins, tragacanth gum, gum arabic, gelatins, collagens, casein, albumin, synthetic or semi-synthetic polymers or glycerides. These formulations can contain, as in conventional cases, further additives, for example, an inactive diluent, a lubricant such as magnesium stearate, a preservative such as paraben or sorbic acid, an anti-oxidant such as ascorbic acid, tocopherol or cysteine, a disintegrator, a binder, a thickening agent, a buffer, a sweetener, a flavoring agent and a perfuming agent. Tablets and pills can further be prepared with enteric coating.

As used herein, "non-orally" includes subcutaneous injection, intravenous injection, intramuscular injections, intraperitoneal injection or instillation. Injectable preparations, for example, sterile injectable aqueous suspensions or oil suspensions can be prepared by known procedures in the fields concerned, using a suitable dispersant or wetting agent and suspending agent. The sterile injections may be, for example, a solution or a suspension, which is prepared with a non-toxic diluent administrable non-orally, such as an aqueous solution, or with a solvent employable for sterile injection. Examples of usable vehicles or acceptable solvents include water, Ringer's solution and an isotonic aqueous saline solution. Further, a sterile non-volatile oil can usually be employed as solvent or suspending agent. A non-volatile oil and a fatty acid can be used

for this purpose, including natural or synthetic or semi-synthetic fatty acid oil or fatty acid, and natural or synthetic mono- or di- or tri-glycerides.

5 The instant pharmaceutical compositions may be formulated for nasal aerosol or inhalation and may be prepared as solutions in saline, and benzyl alcohol or other suitable preservatives, absorption promoters, fluorocarbons, or solubilizing or dispersing agents.

10 Rectal suppositories can be prepared by mixing the drug with a suitable vehicle, for example, cocoa butter and polyethylene glycol, which is in the solid state at ordinary temperatures, in the liquid state at temperatures in intestinal tubes and melts to release the drug.

Examples of liquid preparations for oral administration include pharmaceutically acceptable emulsions, syrups, elixirs, suspensions and solutions, which may contain an inactive diluent, for example, water.

15 The pharmaceutical composition may be easily formulated for topical administration with a suitable ointment containing one or more of the instant compounds suspended or dissolved in a carrier, which include, mineral oil, liquid petroleum, white petroleum, propylene glycol, polyoxyethylene polyoxypropylene compound, emulsifying wax and water. In addition, topical formulations can be formulated with a lotion or cream containing the active
20 compound suspended or dissolved in a carrier. Suitable carriers include mineral oil, sorbitan monostearate, polysorbate 60, cetyl esters wax, cetearyl alcohol, 2-octyldodecanol, benzyl alcohol and water.

25 Dosages of the instant compounds are dependent on age, body weight, general health conditions, sex, diet, dose interval, administration routes, excretion rate, combinations of drugs and conditions of the diseases treated, while taking these and other necessary factors into consideration. Generally, dosage levels

of between about 10 µg per day to about 5000 mg per day, preferably between about 100 mg per day to about 1000 mg per day of the compound are useful in the prevention and treatment of viral infection, including HIV infection. Typically, the pharmaceutical compositions of this invention will be administered from about 1 to about 5 times per day or alternatively, as a continuous infusion. Such administration can be used as a chronic or acute therapy.

The amount of active ingredient that may be combined with the carrier materials to produce a single dosage form will vary depending upon the host treated and the particular mode of administration. A typical preparation will contain from about 5% to about 95% active compound (w/w). Preferably, such preparations contain from about 20% to about 80% active compound.

While these dosage ranges can be adjusted by a necessary unit base for dividing a daily dose, as described above, such doses are decided depending on the diseases to be treated, conditions of such diseases, the age, body weight, general health conditions, sex, diet of the patient then treated, dose intervals, administration routes, excretion rate, and combinations of drugs, while taking these and other necessary factors into consideration. For example, a typical preparation will contain from about .05% to about 95% active compound (w/w). Preferably, such preparations contain from about 10% to about 80% active compound. The desired unit dose of the composition of this invention is administered once or multiple times daily.

Accordingly, a preferred embodiment the instant invention also contemplates compositions and formulations comprising one or more of the instant compounds in combination with one or more other HIV protease inhibitors, reverse transcriptase inhibitors, or non-nucleoside reverse transcriptase inhibitors.

The compounds of this invention may be administered to an uninfected or HIV-infected patient either as a single agent or in combination therapy with other anti-viral agents which interfere with the replication cycle of HIV in order to increase the therapeutic effect of these compounds. Thus, the present invention also relates to a compositions comprising a compound of the present invention, and another antiretroviral compound as a combined preparation for simultaneous, separate or sequential use in treatment of retroviral infections, in particular, in the treatment of infections with multi-drug resistant retroviruses. Thus, to combat or treat HIV infections, or the infection and disease associated with HIV infections, such as Acquired Immunodeficiency Syndrome (ADS) or AIDS Related Complex (ARC), the compounds of this invention may be co-administered in combination with for instance, binding inhibitors, such as, for example, dextran sulfate, suramine, polyanions, soluble CD4, PRO-542, BMS-806; fusion inhibitors, such as, for example, T20, T1249, 5-helix, D-peptide ADS-Ji; co-receptor binding inhibitors, such as, for example, AMD 3100, AMD-3465, AMD7049, AMD3451 (Bicyclams), TAK 779; SHC-C (SCH351125), SHC-D, PRO-140RT inhibitors, such as, for example, foscarnet and prodrugs; nucleoside RTIs, such as, for example, AZT, 3TC, DDC, DDI, D4T, Abacavir, FTC, DAPD, dOTC, DPC 817; nucleotide RTIs, such as, for example, PMEA, PMPA (tenofovir); NNRTIs, such as, for example, nevirapine, delavirdine, efavirenz, 8 and 9-Cl TIBO (tivrapiene), loviride, TMC-125, dapivirine, MKC-442, UC 781, UC 782, Capravirine, DPC 961, DPC963, DPC082, DPC083, calanolide A, SJ- 1366, TSAO, 4'-deaminated TSAO, MVI50, MV026048; RNase H inhibitors, such as, for example, SPI093V, PD126338; TAT inhibitors, such as, for example, RO-5-3335, K12, K37; integrase inhibitors, such as, for example, L 708906, L 731988, S-1360; protease inhibitors, such as, for example, amprenavir and prodrug GW908, ritonavir, nelfinavir, saquinavir, indinavir, lopinavir, palinavir, BMS 186316, atazanavir, DPC 681, DPC 684, tipranavir, AG1776,

mozenavir, GS3333, KNI-413, KNI-272, L754394, L756425, LG-71350, PD161374, PD173606, PD177298, PD178390, PD178392, PNU 140135, TMC114 maslinic acid, U-140690; glycosylation inhibitors, such as, for example, castanospermine, deoxynojirimycine.

- 5 The combination may in some cases provide a synergistic effect, whereby viral infectivity and its associated symptoms may be prevented, substantially reduced, or eliminated completely.

10 The compounds of the present invention may also be administered in combination with immunomodulators (e.g., bropirimine, anti-human alpha interferon antibody, IL-2, methionine enkephalin, interferon alpha, HE-2000 and naltrexone) with antibiotics (e.g., pentamidine isothiorate) cytokines (e.g. Th2), modulators of cytokines, chemokines or the receptors thereof (e.g. CCR5) or hormones (e.g. growth hormone) to ameliorate, combat, or eliminate HIM infection and its symptoms.

- 15 Such combination therapy in different formulations, may be administered simultaneously, separately or sequentially. Alternatively, such combination may be administered as a single formulation, whereby the active ingredients are released from the formulation simultaneously or separately.

20 The compounds of the present invention may also be administered in combination with modulators of the metabolism following application of the drug to an individual. These modulators include compounds that interfere with the metabolism at cytochromes, such as cytochrome P450. Some modulators inhibit cytochrome P450. It is known that several isoenzymes exist of cytochrome P450, one of which is cytochrome P450 3A4. Ritonavir is
25 an example of a modulator of metabolism via cytochrome P450. Such combination therapy in different formulations, may be administered simultaneously, separately or sequentially. Alternatively, such combination

maybe administered as a single formulation, whereby the active ingredients are released from the formulation simultaneously or separately. Such modulator may be administered at the same or different ratio as the compound of the present invention. Preferably, the weight ratio of such modulator vs. a compound of the present invention (modulator:compound of the present invention) is 1:1 or lower, more preferable the ratio is 1:3 or lower, suitably the ratio is 1:10 or lower, more suitably the ratio is 1:30 or lower.

In order to enhance the solubility and/or the stability of the compounds of formula I in pharmaceutical compositions, α , β , or γ cyclodextrins or their derivatives may be employed. Also co-solvents such as alcohols may improve the solubility and/or the stability of the compounds of formula I in pharmaceutical compositions. In the preparation of aqueous compositions, addition salts of the subject compounds may be more suitable due to their increased water solubility.

Appropriate cyclodextrins are α , β , or γ -cyclodextrins (CDs) or ethers and mixed ethers thereof wherein one or more of the hydroxy groups of the anhydroglucose units of the cyclodextrin are substituted with C1-C6alkyl, such as methyl, ethyl or isopropyl, e.g. randomly methylated β -CD; hydroxy C16 alkyl, particularly hydroxy-ethyl, hydroxypropyl or hydroxybutyl; carboxy C1-C6alkyl, particularly carboxymethyl or carboxyethyl; C1-C6alkyl-carbonyl, particularly acetyl; C1-C6 alkyloxycarbonyl C1-C6alkyl or carboxy C16alkyloxy C1-C6alkyl, particularly carboxymethoxypropyl or carboxyethoxypropyl; C1-C6alkylcarbonyloxy C1-C6alkyl, particularly 2-acetyloxypropyl. Especially noteworthy as complexants and/or solubilizers are β -CD, randomly methylated β -CD, 2,6-dimethyl- β -CD, 2-hydroxyethyl- β -CD, 2-hydroxyethyl- γ -CD, hydroxy-propyl- γ -CD and (2-carboxymethoxy)propyl- β -CD, and in particular 2-hydroxy-propyl- β -CD (2-HP- β -CD).

The term mixed ether denotes cyclodextrin derivatives wherein at least two cyclodextrin hydroxy groups are etherified with different groups such as, for example, hydroxy-propyl and hydroxyethyl.

5 The present compounds may be formulated in combination with a cyclodextrin or a derivative thereof as described in EP-A-721,331. Although the formulations described therein are with antifungal active ingredients, they are equally relevant for formulating compounds of the present invention. The formulations described therein are particularly suitable for oral administration and comprise an antifungal as active ingredient, a sufficient amount of a
10 cyclodextrin or a derivative thereof as a solubilizer, an aqueous acidic medium as bulk liquid carrier and an alcoholic co-solvent that greatly simplifies the preparation of the composition. The formulations may also be rendered more palatable by adding pharmaceutically acceptable sweeteners and/or favors.

15 Other convenient ways to enhance the solubility of the compounds of the present invention in pharmaceutical compositions are described in WO 94/05263, WO 98/42318, EP-A-499,299 and WO 97/44014, all incorporated herein by reference.

20 More in particular, the present compounds may be formulated in a pharmaceutical composition comprising a therapeutically effective amount of particles consisting of a solid dispersion comprising a compound of formula I, and one or more pharmaceutically acceptable water-soluble polymers.

25 The term "a solid dispersion" defines a system in a solid state comprising at least two components, wherein one component is dispersed more or less evenly throughout the other component or components. When said dispersion of the components is such that the system is chemically and physically uniform or homogenous throughout or consists of one phase as defined in thermodynamics, such a solid dispersion is referred to as "a solid solution".

Solid solutions are preferred physical systems because the components therein are usually readily bioavailable to the organisms to which they are administered.

5 The term "a solid dispersion" also comprises dispersions which are less homogenous throughout than solid solutions. Such dispersions are not chemically and physically uniform throughout or comprise more than one phase.

10 The water-soluble polymer in the particles is conveniently a polymer that has an apparent viscosity of 1 to 100 mPa.s when dissolved in a 2 % aqueous solution at 20°C.

15 Preferred water-soluble polymers are hydroxypropyl methylcelluloses (HPMC). HPMC having a methoxy degree of substitution from about 0.8 to about 2.5 and a hydroxypropyl molar substitution from about 0.05 to about 3.0 are generally water soluble. Methoxy degree of substitution refers to the average number of methyl ether groups present per anhydroglucose unit of the cellulose molecule. Hydroxypropyl molar substitution refers to the average number of moles of propylene oxide which have reacted with each anhydroglucose unit of the cellulose molecule.

20 The particles as defined hereinabove can be prepared by first preparing a solid dispersion of the components, and then optionally grinding or milling that dispersion. Various techniques exist for preparing solid dispersions including melt-extrusion, spray-drying and solution-evaporation.

25 It may further be convenient to formulate the present compounds in the form of nanoparticles which have a surface modifier adsorbed on the surface thereof in an amount sufficient to maintain an effective average particle size of less than 1000 nm. Useful surface modifiers are believed to include those which

physically adhere to the surface of the antiretroviral agent but do not chemically bond to the antiretroviral agent.

Suitable surface modifiers can preferably be selected from known organic and inorganic pharmaceutical excipients. Such excipients include various polymers, low molecular weight oligomers, natural products and surfactants. Preferred surface modifiers include nonionic and anionic surfactants.

The present compounds may also be incorporated in hydrophilic polymers and applied as a film over many small beads, thus yielding a composition with good bioavailability which can conveniently be manufactured and which is suitable for preparing pharmaceutical dosage forms for oral administration. The beads comprise a central, rounded or spherical core, a coating film of a hydrophilic polymer and an antiretroviral agent and a seal-coating polymer layer. Materials suitable for use as cores are pharmaceutically acceptable and have appropriate dimensions and firmness. Examples of such materials are polymers, inorganic substances, organic substances, saccharides and derivatives thereof. The route of administration may depend on the condition of the subject, co-medication and the like.

The instant compounds and compositions retain inhibitory activity, or potency, over a broad spectrum of related but non-identical retroviral proteases. Accordingly, in another preferred embodiment, the instant invention includes methods for treating or preventing viral infections. Treating or preventing refers to alleviating or hindering symptoms or effects of a viral infection in an infected animal, such as a mammal, particularly a human. Treating includes prophylaxis as well as the treatment of viral infections or symptoms of viral infections. The instant methods comprise treating an animal with a therapeutically effective amount of a compound or composition according to

the instant invention. According to a preferred embodiment, the viral infection is an HIV infection, preferably an mdrHIV infection.

Moreover, the instant compounds and compositions are particularly effective as inhibitors against drug resistant and mdrHIV strains and multi-drug resistant HIV proteases (mdrPR). Accordingly, in another preferred embodiment, the instant invention provides methods for inhibiting HIV protease, particularly drug resistant and multi-drug resistant HIV proteases (mdrPR), with a therapeutically effective amount of a compound or composition according to the instant invention.

In relation to the above, the instant compounds may be used in vaccines for protecting individuals against viral, specifically, mdrHIV infections. As such, the instant compounds may be employed as protease inhibitors as conventionally used in vaccines. In this regard, one or more of the instant compounds may be combined with a pharmaceutically acceptable adjuvant conventionally employed in vaccines and administered in prophylactically effective amounts to protect individuals over an extended period time against HIV infection.

The present invention also relates to a novel compositions and a methods for improving the pharmacokinetics of drugs which are metabolized by cytochrome P450 monooxygenase. In addition, the present invention relates to a novel composition and a method for inhibiting retroviral proteases and in particular for inhibiting human immunodeficiency virus (HIV) protease and a composition and a method for inhibiting a retroviral infection, in particular an HIV infection.

In this connection, the present invention provides a method of improving the pharmacokinetics of a drug (or a pharmaceutically acceptable salt thereof) which is metabolized by cytochrome P450 monooxygenase comprising

coadministering a compound of the instant invention or a pharmaceutically acceptable salt thereof. When administered in combination, the two therapeutic agents can be formulated as separate compositions which are administered at the same time or different times, or the two therapeutic agents can be administered as a single composition.

Drugs which are metabolized by cytochrome P450 monooxygenase and which benefit from coadministration with a compound of the instant invention include, but are not limited to, ritonavir, the immunosuppressants cyclosporine, FK-506 and rapamycin, the chemotherapeutic agents taxol and taxotere, the antibiotic clarithromycin and the HIV protease inhibitors A-77003, A-80987, MK-639, saquinavir, VX-478, AG1343, DMP-323, XM-450, BILA 2011 BS, BILA 1096 BS, BILA 2185 BS, BMS 186,318, LB71262, SC-52151, SC-629 (N,N-dimethylglycyl-N-(2-hydroxy-3-(((4-methoxyphenyl)sulphonyl)(2-methylpropyl)amino)-1-(phenylmethyl)propyl)-3-methyl-L-valinamide), KNI-272, CGP 53437, CGP 57813 and U-103017.

In a preferred embodiment of the present invention, there is disclosed a method for improving the pharmacokinetics of an HIV protease inhibitor (or a pharmaceutically acceptable salt thereof) which is metabolized by cytochrome P450 monooxygenase comprising coadministering a compound of the instant invention or a pharmaceutically acceptable salt thereof. Such a combination of a compound of the instant invention or a pharmaceutically acceptable salt thereof and an HIV protease inhibitor or a pharmaceutically acceptable salt thereof which is metabolized by cytochrome P450 monooxygenase is useful for inhibiting HIV protease in humans and is also useful for inhibition, treatment or prophylaxis of an HIV infection or AIDS (acquired immune deficiency syndrome) in humans. When administered in combination, the two therapeutic agents can be formulated as separate compositions which are

administered at the same time or different times, or the two therapeutic agents can be administered as a single composition.

The following examples illustrate further the present invention but, of course, should not be construed in any way of limiting its scope.

EXAMPLES

Example 1

This example describes the antiviral activity, resistance profile, and selection of resistance mutations for a resistance-repellent PI (UIC-94003, Fig. 1; also referred to as compound 1, *vide infra*). Also described in this example is a preliminary analysis by computer modeling of the structural basis of the resistance-repellent properties of 1.

Compound 1 was originally identified as a potent protease inhibitor of multidrug drug resistant HIV mutants using a novel biochemical fitness profiling strategy described in Erickson and Gulnik, WO 99/67417, which application is included herein in its entirety. The biochemical resistance profile ($K_{i,mutant}/K_{i,wild\ type}$) and biochemical fitness, or vitality, profile ($K_{i,mutant}/K_{i,wild\ type} \times (k_{cat,mutant}/K_{m,mutant})/(k_{cat,wild\ type}/K_{m,wild\ type})$) of compound 1 is described in Table 1 in Example 13 (as Compound 32) of Erickson and Gulnik, *vide supra*. Antiviral potencies against wild type and multi-drug resistant HIV strains are described in Table 3 in Example 14 of Erickson and Gulnik, *vide supra*. Based on the biochemical fitness and antiviral drug resistance profiles, it was predicted that drug resistant viruses containing the characteristic mutations described in Erickson and Gulnik WO 99/67417 would not emerge from the wild type virus in the presence of 1. This prediction was largely borne out in the present example, which provides new data on the selection of mutations using compound 1, as well as additional

biological and structural data related to the antiviral and resistance-repellent properties of compound 1. Data from the present example are described in detail in Yoshimura et al., *J. Virol.*, 76, 1349-1358 (2002).

In vitro drug sensitivity of HIV-1 laboratory isolates to Compound 1 and other PIs

The sensitivities of HIV-1_{LAI}, HIV-1_{Ba-L}, HIV-2_{EHO} and the primary HIV-1 isolates against various drugs were determined as previously described with minor modifications (Shiraska et al., *Proc. Natl. Acad. Sci. USA*, 92, 2398-2402 (1995)). The antiviral activity of 1 was >10-fold more potent than any of the five currently available PIs against both HIV-1_{LAI} and HIV-1_{Ba-L} in PHA-PBMC (IC₅₀: 0.0003 μM) (Table 1).

In vitro activity of Compound 1 against highly PI-resistant clinical HIV-1 strains

Compound 1 was also active against highly cross-resistant HIV-1 strains derived from AIDS patients who had failed on 9 to 11 anti-HIV-1 drugs (Falloon et al., *Clin. Infect. Dis.*, 30, 313-318 (2000); Yoshimura et al., *Proc. Natl. Acad. Sci. USA*, 96, 8675-8680 (1999)). These HIV-1 strains contained up to fourteen amino acid substitutions in the protease-encoding region, and had high-level resistance to RTV, IDV, NFV and APV (6- to >77-fold), and moderate-to-high level resistance to SQV (3-31-fold), as compared to a wild-type clinical strain HIV-1_{ERS104pre}. In contrast, 1 suppressed the replication of all eight isolates with IC₅₀ values ranging 0.0005-0.0055 μM (Table 2). While two strains (strains 1 and 7) were 6- and 8-fold less susceptible to 1, the IC₅₀ values remained extremely low, 0.004 and 0.0055 μM, respectively (Table 2).

Generation of Compound 1-resistant HIV-1 *in vitro*.

Selection of HIV-1 variants resistant to Compound 1 and a structurally-related PI, amprenavir, was performed *in vitro* by propagating HIV-1NL4-3 in MT-2 cells in the presence of increasing concentrations of drug as described in Yoshimura et al., (2002), *vide supra*. The virus required 32 passages to acquire a 100-fold increase in the highest compound 1 concentration at which the virus could propagate while it required only 21 passages for the virus to acquire the same level of resistance against amprenavir (Figure 2). For the virus to acquire a 500-fold increase to compound 1, 46 passages were required, while 31 passages were required for viral acquisition of the same level of resistance against APV (Figure 2).

Nucleotide sequencing of proviral DNAs from the lysates of infected cells was used to determine the mutations selected by each drug. Individual protease sequences and their frequency at each passage are depicted in Figure 3. The wild-type protease gene sequence was seen in 8 of 8 clones derived from HIV-1NL4-3 at passage 4 (HIV-1UIC-P4). An A28S mutation at the active site of the enzyme was seen early (at passage 15) in 5 of 9 clones of HIV-1UIC-P15, and it was subsequently seen consistently at frequencies of >50% (except 44% for HIV-1P42), suggesting that this mutation was critical in conferring resistance to compound 1. A substitution at residue 50 from Ile to Val, seen in HIV-1 resistant to APV (8, 26), was also identified at passage 26 and beyond. It appeared that the I50V mutation brought about a significant change in protease since the virus started to replicate relatively rapidly in the presence of compound 1 following the emergence of I50V (Figure 2). It is noteworthy that these two active site mutations, A28S and I50V, did not co-exist in any clones except in 3 clones throughout the selection (Figure 3). Compensatory, non-

active site mutations that were selected at later passages included L10F, M46I and A71V.

Sensitivity of Compound 1-selected HIV-1 to various PIs

Viruses at passage 62 with 2 μ M 1 (HIV-1UIC-P62) and those at passage 30 with 5 μ M APV (HIV-1APV-P30) were titrated, and their susceptibilities to 1, APV, and several other PIs were determined (Table 3). HIV-1UIC-P62 was highly resistant to APV and 1 (IC₅₀ values were 20- and 70-fold greater than that of HIV-1NL4-3, respectively). However, HIV-1UIC-P62 was as sensitive to RTV and SQV as the parental HIV-1NL4-3, while it was moderately resistant to IDV and NFV (7- and 5-fold increases in IC₅₀ values, respectively). In contrast, HIV-1APV-P30 was highly resistant to all PIs tested except SQV (Table 3). These data suggest that 1 has significant advantages compared to APV in terms of the emergence of drug resistance: (i) the viral acquisition of resistance to 1 is substantially delayed (Figure 2); (ii) 1 resistant HIV remains sensitive to all PIs except APV; and, (iii) in contrast, APV-resistant virus is highly cross-resistant to all PIs, except SQV (Table 3).

Molecular modeling of interaction of HIV-1 protease and Compound 1

A structural model of HIV-1 protease complexed with Compound 1 was prepared based on the crystal structures of HIV-1 protease complexed with APV (Kim et al., *J. Amer. Chem. Soc.*, 117, 1181 (1995)) and with compound 49 (Ghosh et al., *J. Med. Chem.*, 37, 1506-2508). These two structures were chosen because Compound 1 is closely related in structure to APV, except for the presence of the P2 bis-THF moiety, which is contained in compound 49. Figure 4 shows an optimized molecular model of the protease-1 complex, and illustrates the locations of amino acid residues where substitutions were identified in HIV-1P62. Ile50 is located on the internal surface of the flap of

HIV-1 protease from where its aliphatic side chain atoms making van der Waals contacts with inhibitor atoms. Ala28 is located between the conserved catalytic triad, Asp25-Thr26-Gly27, and two major substrate and inhibitor binding residues, Asp29 and Asp30, but is not itself directly involved in binding. Met46 is located on the external surface of the flap of HIV protease. Ile10, Asn88, and Ala71 are located far from the active site of the enzyme. These mutations presumably improve the fitness of active site-containing mutants by exerting long-range effects on inhibitor or substrate binding, or by some other compensatory mechanism (Erickson and Burt, (1996) *vide supra*; Erickson et al., AIDS, (1999) *vide supra*).

The model also showed that, using the bound conformation of APV for compound 1, the two oxygen atoms of the *bis*-THF group of compound 1 could be positioned to form hydrogen bonds with the main chain amides of Asp29 and Asp30 in a manner similar to that observed previously for compound 49 (Figure 5). In the model, compound 1 does not make any interactions with Ala28 (Figure 5). This is consistent with the structure of the APV/protease complex, in which Ala28 also does not play a direct role in binding.

The high potency of Compound 1 relative to APV is consistent with previous studies that have shown an increase in potency when a THF group is replaced by a fused ring *bis*-THF moiety (Ghosh et al., *Bioorg. Med. Chem. Lett.*, 8, 687-690 (1998); Ghosh et al., (1994), *vide supra*). The modeling analysis suggests that the increased potency appears to stem from the ability of the two, conformationally-constrained, ring oxygen atoms in the *bis*-THF group to form hydrogen bonds with the the main chain amide hydrogen atoms of Asp29 and Asp30 in the S2 subsite (Figure 5). Since the main chain atoms cannot mutate, these interactions may be important for 1's broad spectrum of activity against multi-drug resistant variants.

No amino acid mutations were seen (except at early passages during the selection of HIV-1 with 1) at the two active site residues, Val82 and Ile84, whose side chains are involved in making direct contacts with all PIs. Mutations at these two active sites are commonly seen in HIV-1 resistant to various PIs. Mutations at Val82 are highly effective at conferring resistance and, when combined with a second active site mutation, such as V32I, can result in widespread biochemical cross-resistance to PIs.. The Ile84 residue, along with the symmetry-related I84', makes interactions across S2/S1' and S1/S2' subsites, respectively, and the I84V mutation has been observed in clinical resistance with various PIs including RTV, IDV, SQV, and APV. HIV-1 propagated in the presence of compound 1 did not attain stable mutations at V82, and did not acquire those at I84V (except for one clone), indicating that the acquisition of resistance to this PI by wild type HIV-1 may require different evolutionary pathways than have been heretofore observed for most PIs.

The D30N mutation is a primary resistance mutation for nelfinavir, which forms a hydrogen bond with the side chain of Asp30). and has no effect on binding of compound 1. Consistent with these observations, HIV-1 exposed to 1 does not select mutations at codon 30.

Infectious clones containing either A28S or I50V in the pNL4-3 background replicated poorly compared to HIV-1_{wt} in MT-2 cells (data not shown). In a published biochemical study, the A28S mutation in HIV protease caused a more than 1,500-fold decrease in K_{cat}/K_m values for peptide substrates (Hong, et al., *Protein Sci.*, 7, 300-305 (1998)). These results suggest that, while the A28S mutation represents a critical mutation for resistance to 1, it confers a severe replication disadvantage on the virus.

When HIV-1_{NL4-3} was propagated in the presence of increasing concentrations of 1 or APV, the appearance of HIV-1 strains that were highly resistant to 1 were delayed compared to the appearance of HIV-1 strains highly resistant to APV (Figure 2). Taken together, the above data are consistent with the prediction that compound 1 is a "resistance-repellent" PI as defined above.

These data suggest that 1 and other compounds having the general structure described herein have at least four advantages: (i) they exert potent activity against a wide spectrum of drug-resistant HIV-1 variants presumably due to their interaction with the main chains of the active site amino acids (Asp29 and Asp30); and (ii) their unique contact with HIV-1 protease is different from that of other PIs; (iii) the viral acquisition of resistance is substantially delayed; and (iv) at least several PIs remain active *in vitro* against the virus selected *in vitro* with 1 or the other compounds (Table 3).

Example 2

This example illustrates the method by which experimentally-determined crystal structures of the same inhibitor in complex with wild type and mutant species of HIV protease can be compared and analyzed for the existence of a three-dimensionally conserved substructure.

The structures of wild type HIV-1 protease and a mutant, V82F/I84V, HIV-1 protease, both in complexes with the inhibitor shown in Figure 1 were determined using conventional x-ray crystallography techniques. The structures were analyzed by means of (a) an overall superposition of the atoms of the protein structures; and, (b) a study of the distances from polar atoms of the inhibitors to polar atoms of the protein. This analysis requires three dimensional atomic coordinates of the protein structures and of the bound inhibitor.

The superposition of the protein structures was performed in a two step process: 1) the distance between all pairs of corresponding Ca atoms (Ca atom of residue number 1 in one protein to Ca atom of residue number 1 in the second protein; Ca atom of residue number 2 in one protein to Ca atom of residue number 2 in the second protein; and so on) of the polypeptide chains is minimized by means of a least-square algorithm; 2) the superposition is refined by minimizing, in an iterative process, the distances between corresponding Ca atoms that are closer than a given distance (0.25 Å in this example), thus eliminating regions of the structures having large conformational differences to compute the superposition parameters. The distances between equivalenced Ca atoms after the minimization procedure are shown in Table 4.

Table 4

Distances between equivalent Ca atoms

Molecule 1: HIV-1 PR wt: 1

Molecule 2: HIV-1 PR V82F/I84V mutant: 1

Molecule 1			Molecule 2			distance [Å]
CA	PRO	1	CA	PRO	1	0.455
CA	GLN	2	CA	GLN	2	0.434
CA	ILE	3	CA	ILE	3	0.418
CA	THR	4	CA	THR	4	0.317
CA	LEU	5	CA	LEU	5	0.172
CA	TRP	6	CA	TRP	6	0.228
CA	GLN	7	CA	GLN	7	0.364
CA	ARG	8	CA	ARG	8	0.166
CA	PRO	9	CA	PRO	9	0.057
CA	LEU	10	CA	LEU	10	0.183
CA	VAL	11	CA	VAL	11	0.194
CA	THR	12	CA	THR	12	0.168
CA	ILE	13	CA	ILE	13	0.146
CA	LYS	14	CA	LYS	14	0.229

Molecule 1			Molecule 2			distance [Å]
CA	ILE	15	CA	ILE	15	0.266
CA	GLY	16	CA	GLY	16	0.662
CA	GLY	17	CA	GLY	17	0.491
CA	GLN	18	CA	GLN	18	0.267
CA	LEU	19	CA	LEU	19	0.112
CA	LYS	20	CA	LYS	20	0.128
CA	GLU	21	CA	GLU	21	0.190
CA	ALA	22	CA	ALA	22	0.169
CA	LEU	23	CA	LEU	23	0.218
CA	LEU	24	CA	LEU	24	0.233
CA	ASP	25	CA	ASP	25	0.160
CA	THR	26	CA	THR	26	0.200
CA	GLY	27	CA	GLY	27	0.303
CA	ALA	28	CA	ALA	28	0.169
CA	ASP	29	CA	ASP	29	0.150
CA	ASP	30	CA	ASP	30	0.038
CA	THR	31	CA	THR	31	0.047
CA	VAL	32	CA	VAL	32	0.173
CA	LEU	33	CA	LEU	33	0.194
CA	GLU	34	CA	GLU	34	0.310
CA	GLU	35	CA	GLU	35	0.260
CA	MET	36	CA	MET	36	0.136
CA	SER	37	CA	SER	37	0.494
CA	LEU	38	CA	LEU	38	0.607
CA	PRO	39	CA	PRO	39	0.094
CA	GLY	40	CA	GLY	40	0.774
CA	ARG	41	CA	ARG	41	0.448
CA	TRP	42	CA	TRP	42	0.204
CA	LYS	43	CA	LYS	43	0.596
CA	PRO	44	CA	PRO	44	0.625
CA	LYS	45	CA	LYS	45	0.541
CA	MET	46	CA	MET	46	0.643
CA	ILE	47	CA	ILE	47	0.361
CA	GLY	48	CA	GLY	48	0.240
CA	GLY	49	CA	GLY	49	0.182
CA	ILE	50	CA	ILE	50	0.110
CA	GLY	51	CA	GLY	51	0.243
CA	GLY	52	CA	GLY	52	0.200
CA	PHE	53	CA	PHE	53	0.119
CA	ILE	54	CA	ILE	54	0.255
CA	LYS	55	CA	LYS	55	0.295
CA	VAL	56	CA	VAL	56	0.108
CA	ARG	57	CA	ARG	57	0.129
CA	GLN	58	CA	GLN	58	0.074
CA	TYR	59	CA	TYR	59	0.372
CA	ASP	60	CA	ASP	60	0.496

Molecule 1			Molecule 2			distance [Å]
CA	GLN	61	CA	GLN	61	0.780
CA	ILE	62	CA	ILE	62	0.406
CA	LEU	63	CA	LEU	63	0.211
CA	ILE	64	CA	ILE	64	0.260
CA	GLU	65	CA	GLU	65	0.193
CA	ILE	66	CA	ILE	66	0.181
CA	CYS	67	CA	CYS	67	0.518
CA	GLY	68	CA	GLY	68	0.641
CA	HIS	69	CA	HIS	69	0.319
CA	LYS	70	CA	LYS	70	0.179
CA	ALA	71	CA	ALA	71	0.265
CA	ILE	72	CA	ILE	72	0.350
CA	GLY	73	CA	GLY	73	0.253
CA	THR	74	CA	THR	74	0.301
CA	VAL	75	CA	VAL	75	0.187
CA	LEU	76	CA	LEU	76	0.186
CA	VAL	77	CA	VAL	77	0.070
CA	GLY	78	CA	GLY	78	0.306
CA	PRO	79	CA	PRO	79	0.047
CA	THR	80	CA	THR	80	0.470
CA	PRO	81	CA	PRO	81	0.404
CA	VAL	82	CA	PHE	82	0.556
CA	ASN	83	CA	ASN	83	0.146
CA	ILE	84	CA	VAL	84	0.196
CA	ILE	85	CA	ILE	85	0.163
CA	GLY	86	CA	GLY	86	0.224
CA	ARG	87	CA	ARG	87	0.127
CA	ASN	88	CA	ASN	88	0.048
CA	LEU	89	CA	LEU	89	0.081
CA	LEU	90	CA	LEU	90	0.197
CA	THR	91	CA	THR	91	0.226
CA	GLN	92	CA	GLN	92	0.176
CA	ILE	93	CA	ILE	93	0.151
CA	GLY	94	CA	GLY	94	0.338
CA	CYS	95	CA	CYS	95	0.233
CA	THR	96	CA	THR	96	0.305
CA	LEU	97	CA	LEU	97	0.089
CA	ASN	98	CA	ASN	98	0.260
CA	PHE	99	CA	PHE	99	0.250
CA	PRO	101	CA	PRO	101	0.227
CA	GLN	102	CA	GLN	102	0.108
CA	ILE	103	CA	ILE	103	0.206
CA	THR	104	CA	THR	104	0.169
CA	LEU	105	CA	LEU	105	0.125
CA	TRP	106	CA	TRP	106	0.363
CA	GLN	107	CA	GLN	107	0.296

Molecule 1			Molecule 2			distance [Å]
CA	ARG	108	CA	ARG	108	0.400
CA	PRO	109	CA	PRO	109	0.173
CA	LEU	110	CA	LEU	110	0.182
CA	VAL	111	CA	VAL	111	0.085
CA	THR	112	CA	THR	112	0.123
CA	ILE	113	CA	ILE	113	0.107
CA	LYS	114	CA	LYS	114	0.368
CA	ILE	115	CA	ILE	115	0.226
CA	GLY	116	CA	GLY	116	0.638
CA	GLY	117	CA	GLY	117	0.516
CA	GLN	118	CA	GLN	118	0.414
CA	LEU	119	CA	LEU	119	0.102
CA	LYS	120	CA	LYS	120	0.191
CA	GLU	121	CA	GLU	121	0.206
CA	ALA	122	CA	ALA	122	0.197
CA	LEU	123	CA	LEU	123	0.231
CA	LEU	124	CA	LEU	124	0.145
CA	ASP	125	CA	ASP	125	0.235
CA	THR	126	CA	THR	126	0.311
CA	GLY	127	CA	GLY	127	0.200
CA	ALA	128	CA	ALA	128	0.102
CA	ASP	129	CA	ASP	129	0.143
CA	ASP	130	CA	ASP	130	0.261
CA	THR	131	CA	THR	131	0.172
CA	VAL	132	CA	VAL	132	0.232
CA	LEU	133	CA	LEU	133	0.103
CA	GLU	134	CA	GLU	134	0.175
CA	GLU	135	CA	GLU	135	0.190
CA	MET	136	CA	MET	136	0.220
CA	SER	137	CA	SER	137	0.739
CA	LEU	138	CA	LEU	138	0.277
CA	PRO	139	CA	PRO	139	0.325
CA	GLY	140	CA	GLY	140	0.390
CA	ARG	141	CA	ARG	141	0.174
CA	TRP	142	CA	TRP	142	0.168
CA	LYS	143	CA	LYS	143	0.304
CA	PRO	144	CA	PRO	144	0.194
CA	LYS	145	CA	LYS	145	0.456
CA	MET	146	CA	MET	146	0.362
CA	ILE	147	CA	ILE	147	0.178
CA	GLY	148	CA	GLY	148	0.390
CA	GLY	149	CA	GLY	149	0.434
CA	ILE	150	CA	ILE	150	0.050
CA	GLY	151	CA	GLY	151	0.199
CA	GLY	152	CA	GLY	152	0.152
CA	PHE	153	CA	PHE	153	0.455

Molecule 1	Molecule 2	distance [Å]
CA ILE 154	CA ILE 154	0.198
CA LYS 155	CA LYS 155	0.470
CA VAL 156	CA VAL 156	0.590
CA ARG 157	CA ARG 157	0.607
CA GLN 158	CA GLN 158	0.465
CA TYR 159	CA TYR 159	0.301
CA ASP 160	CA ASP 160	0.294
CA GLN 161	CA GLN 161	0.308
CA ILE 162	CA ILE 162	0.274
CA LEU 163	CA LEU 163	0.235
CA ILE 164	CA ILE 164	0.367
CA GLU 165	CA GLU 165	0.410
CA ILE 166	CA ILE 166	0.201
CA CYS 167	CA CYS 167	0.409
CA GLY 168	CA GLY 168	0.406
CA HIS 169	CA HIS 169	0.410
CA LYS 170	CA LYS 170	0.282
CA ALA 171	CA ALA 171	0.273
CA ILE 172	CA ILE 172	0.317
CA GLY 173	CA GLY 173	0.563
CA THR 174	CA THR 174	0.129
CA VAL 175	CA VAL 175	0.237
CA LEU 176	CA LEU 176	0.155
CA VAL 177	CA VAL 177	0.240
CA GLY 178	CA GLY 178	0.386
CA PRO 179	CA PRO 179	0.340
CA THR 180	CA THR 180	0.335
CA PRO 181	CA PRO 181	0.446
CA VAL 182	CA PHE 182	0.343
CA ASN 183	CA ASN 183	0.205
CA ILE 184	CA VAL 184	0.262
CA ILE 185	CA ILE 185	0.096
CA GLY 186	CA GLY 186	0.118
CA ARG 187	CA ARG 187	0.202
CA ASN 188	CA ASN 188	0.073
CA LEU 189	CA LEU 189	0.108
CA LEU 190	CA LEU 190	0.127
CA THR 191	CA THR 191	0.177
CA GLN 192	CA GLN 192	0.175
CA ILE 193	CA ILE 193	0.241
CA GLY 194	CA GLY 194	0.118
CA CYS 195	CA CYS 195	0.375
CA THR 196	CA THR 196	0.437
CA LEU 197	CA LEU 197	0.167
CA ASN 198	CA ASN 198	0.178

Molecule 1	Molecule 2	distance [Å]

Table 4 shows that the I84V, V82F mutations induce structural changes relative to the wild type structure in some parts of the enzyme, but that other regions are less affected. The regions of the protein structure which are not significantly affected by the amino acid mutations are defined as *structurally conserved* regions. In the present example, the mutations result in localized structural changes in the backbone of HIV protease over a wide range, from 0.038-0.774 Å.

The distances between the polar atoms of the inhibitor shown in Figure 1 to polar atoms of the wild type and mutant protein, that is hydrogen-bond donors and acceptors, were computed and they are displayed in Table 5.

Table 5

Distances between polar atoms of the inhibitor and polar atoms of the protein

	HIV PR wt: 1	V82F/I84V: 1
O2-Wat301	2.92	2.89
N1-O27	3.36	3.46
O6-N30	3.30	3.61
O6-N29	3.19	3.55
O7-N29	2.84	2.87
O7-OD1 29	3.42	3.54
O7-O1	3.31	3.19
O3-OD 25 (out)	2.5 0	2.94

O3-OD 25 (in)	2.65	2.67
O3-OD125 (out)	3.27	3.21
O3-OD125 (in)	2.80	2.67
O5-Wat301	2.70	2.79
O8-N130	3.16	2.96

Table 5 shows that the polar atoms of the inhibitor interact with the same polar atoms of the two different proteins, in this case the wild type and V82F/I84V mutant HIV proteases. From Table 5, it can be seen that the polar atoms of the enzymes with which the inhibitor interacts belong to the structurally conserved regions. The effects of mutations on the protein-inhibitor interactions can be quantified in terms of the distances between interacting pairs of polar atoms from the inhibitor and from polar atoms of the three-dimensionally conserved substructure of the protein. These distances are similar in the wild type and in the mutant complexes; the average of their differences is only 0.07 Å. The range of the differences is 0.02-0.36 Å.

Example 3

This example illustrates the method by which experimentally-determined crystal structures of two different inhibitors in complexes with wild type HIV protease can be compared and analyzed for the existence of a three-dimensionally conserved substructure. The structures of wild type HIV-1 protease in complexes with inhibitor 1 and with Amprenavir (inhibitor 2) were analyzed by means of (a) an overall superposition of the protein structures; and (b) a study of the distances from polar atoms of the inhibitors to polar atoms of the protein.

The superposition of the protein structures is performed in a two step process: 1) the distance between all pairs of corresponding C α atoms (C α atom of

- residue number 1 in one protein to Ca atom of residue number 1 in the second protein; Ca atom of residue number 2 in one protein to Ca atom of residue number 2 in the second protein; and so on) of the polypeptide chains is minimized by means of a least-square algorithm; 2) the superposition is refined by minimizing, in an iterative process, the distances between corresponding Ca atoms that are closer than a given distance (0.25 Å in this example), thus eliminating regions of the structures having large conformational differences to compute the superposition parameters. The distances between equivalenced Ca atoms after the minimization procedure are shown in Table 6.

Table 6

Distances between equivalent Ca atoms

Molecule 1: HIV-1 PR wt: 1

Molecule 2: HIV-1 PR wt: 2

Molecule 1			Molecule 2			distance [Å]
CA	PRO	1	CA	PRO	1	0.200
CA	GLN	2	CA	GLN	2	0.320
CA	ILE	3	CA	ILE	3	0.147
CA	THR	4	CA	THR	4	0.405
CA	LEU	5	CA	LEU	5	0.225
CA	TRP	6	CA	TRP	6	0.296
CA	GLN	7	CA	GLN	7	0.317
CA	ARG	8	CA	ARG	8	0.154
CA	PRO	9	CA	PRO	9	0.143
CA	LEU	10	CA	LEU	10	0.259
CA	VAL	11	CA	VAL	11	0.275
CA	THR	12	CA	THR	12	0.307
CA	ILE	13	CA	ILE	13	0.207
CA	LYS	14	CA	LYS	14	0.273
CA	ILE	15	CA	ILE	15	0.434
CA	GLY	16	CA	GLY	16	0.469

Molecule 1			Molecule 2			distance [Å]
CA	GLY	17	CA	GLY	17	0.414
CA	GLN	18	CA	GLN	18	0.319
CA	LEU	19	CA	LEU	19	0.161
CA	LYS	20	CA	LYS	20	0.155
CA	GLU	21	CA	GLU	21	0.196
CA	ALA	22	CA	ALA	22	0.338
CA	LEU	23	CA	LEU	23	0.246
CA	LEU	24	CA	LEU	24	0.292
CA	ASP	25	CA	ASP	25	0.142
CA	THR	26	CA	THR	26	0.109
CA	GLY	27	CA	GLY	27	0.176
CA	ALA	28	CA	ALA	28	0.193
CA	ASP	29	CA	ASP	29	0.087
CA	ASP	30	CA	ASP	30	0.118
CA	THR	31	CA	THR	31	0.111
CA	VAL	32	CA	VAL	32	0.087
CA	LEU	33	CA	LEU	33	0.306
CA	GLU	34	CA	GLU	34	0.333
CA	GLU	35	CA	GLU	35	0.399
CA	MET	36	CA	MET	36	0.296
CA	SER	37	CA	SER	37	0.454
CA	LEU	38	CA	LEU	38	0.451
CA	PRO	39	CA	PRO	39	0.397
CA	GLY	40	CA	GLY	40	0.444
CA	ARG	41	CA	ARG	41	0.535
CA	TRP	42	CA	TRP	42	0.346
CA	LYS	43	CA	LYS	43	0.442
CA	PRO	44	CA	PRO	44	0.548
CA	LYS	45	CA	LYS	45	0.307
CA	MET	46	CA	MET	46	0.320
CA	ILE	47	CA	ILE	47	0.403
CA	GLY	48	CA	GLY	48	0.237
CA	GLY	49	CA	GLY	49	0.280
CA	ILE	50	CA	ILE	50	0.206
CA	GLY	51	CA	GLY	51	0.368
CA	GLY	52	CA	GLY	52	0.315
CA	PHE	53	CA	PHE	53	0.378
CA	ILE	54	CA	ILE	54	0.180
CA	LYS	55	CA	LYS	55	0.149
CA	VAL	56	CA	VAL	56	0.302
CA	ARG	57	CA	ARG	57	0.098
CA	GLN	58	CA	GLN	58	0.219
CA	TYR	59	CA	TYR	59	0.279
CA	ASP	60	CA	ASP	60	0.385
CA	GLN	61	CA	GLN	61	0.431

Molecule 1			Molecule 2			distance [Å]
CA	ILE	62	CA	ILE	62	0.343
CA	LEU	63	CA	LEU	63	0.473
CA	ILE	64	CA	ILE	64	0.344
CA	GLU	65	CA	GLU	65	0.456
CA	ILE	66	CA	ILE	66	0.481
CA	CYS	67	CA	CYS	67	0.920
CA	GLY	68	CA	GLY	68	0.999
CA	HIS	69	CA	HIS	69	0.295
CA	LYS	70	CA	LYS	70	0.406
CA	ALA	71	CA	ALA	71	0.446
CA	ILE	72	CA	ILE	72	0.374
CA	GLY	73	CA	GLY	73	0.259
CA	THR	74	CA	THR	74	0.276
CA	VAL	75	CA	VAL	75	0.165
CA	LEU	76	CA	LEU	76	0.220
CA	VAL	77	CA	VAL	77	0.202
CA	GLY	78	CA	GLY	78	0.231
CA	PRO	79	CA	PRO	79	0.131
CA	THR	80	CA	THR	80	0.374
CA	PRO	81	CA	PRO	81	0.472
CA	VAL	82	CA	VAL	82	0.554
CA	ASN	83	CA	ASN	83	0.149
CA	ILE	84	CA	ILE	84	0.261
CA	ILE	85	CA	ILE	85	0.223
CA	GLY	86	CA	GLY	86	0.130
CA	ARG	87	CA	ARG	87	0.165
CA	ASN	88	CA	ASN	88	0.103
CA	LEU	89	CA	LEU	89	0.072
CA	LEU	90	CA	LEU	90	0.076
CA	THR	91	CA	THR	91	0.114
CA	GLN	92	CA	GLN	92	0.115
CA	ILE	93	CA	ILE	93	0.204
CA	GLY	94	CA	GLY	94	0.220
CA	CYS	95	CA	CYS	95	0.068
CA	THR	96	CA	THR	96	0.185
CA	LEU	97	CA	LEU	97	0.095
CA	ASN	98	CA	ASN	98	0.311
CA	PHE	99	CA	PHE	99	0.216
CA	PRO	101	CA	PRO	1	0.455
CA	GLN	102	CA	GLN	2	0.121
CA	ILE	103	CA	ILE	3	0.120
CA	THR	104	CA	THR	4	0.109
CA	LEU	105	CA	LEU	5	0.128
CA	TRP	106	CA	TRP	6	0.205
CA	GLN	107	CA	GLN	7	0.229

Molecule 1			Molecule 2			distance [Å]
CA	ARG	108	CA	ARG	8	0.211
CA	PRO	109	CA	PRO	9	0.195
CA	LEU	110	CA	LEU	10	0.135
CA	VAL	111	CA	VAL	11	0.086
CA	THR	112	CA	THR	12	0.166
CA	ILE	113	CA	ILE	13	0.199
CA	LYS	114	CA	LYS	14	0.333
CA	ILE	115	CA	ILE	15	0.356
CA	GLY	116	CA	GLY	16	0.671
CA	GLY	117	CA	GLY	17	0.709
CA	GLN	118	CA	GLN	18	0.370
CA	LEU	119	CA	LEU	19	0.258
CA	LYS	120	CA	LYS	20	0.156
CA	GLU	121	CA	GLU	21	0.250
CA	ALA	122	CA	ALA	22	0.276
CA	LEU	123	CA	LEU	23	0.103
CA	LEU	124	CA	LEU	24	0.112
CA	ASP	125	CA	ASP	25	0.078
CA	THR	126	CA	THR	26	0.057
CA	GLY	127	CA	GLY	27	0.121
CA	ALA	128	CA	ALA	28	0.098
CA	ASP	129	CA	ASP	29	0.190
CA	ASP	130	CA	ASP	30	0.302
CA	THR	131	CA	THR	31	0.073
CA	VAL	132	CA	VAL	32	0.178
CA	LEU	133	CA	LEU	33	0.147
CA	GLU	134	CA	GLU	34	0.239
CA	GLU	135	CA	GLU	35	0.101
CA	MET	136	CA	MET	36	0.235
CA	SER	137	CA	SER	37	0.391
CA	LEU	138	CA	LEU	38	0.364
CA	PRO	139	CA	PRO	39	0.532
CA	GLY	140	CA	GLY	40	0.213
CA	ARG	141	CA	ARG	41	0.448
CA	TRP	142	CA	TRP	42	0.133
CA	LYS	143	CA	LYS	43	0.195
CA	PRO	144	CA	PRO	44	0.082
CA	LYS	145	CA	LYS	45	0.359
CA	MET	146	CA	MET	46	0.306
CA	ILE	147	CA	ILE	47	0.076
CA	GLY	148	CA	GLY	48	0.214
CA	GLY	149	CA	GLY	49	0.205
CA	ILE	150	CA	ILE	50	0.163
CA	GLY	151	CA	GLY	51	0.287
CA	GLY	152	CA	GLY	52	0.318

Molecule 1			Molecule 2			distance [Å]
CA	PHE	153	CA	PHE	53	0.125
CA	ILE	154	CA	ILE	54	0.189
CA	LYS	155	CA	LYS	55	0.384
CA	VAL	156	CA	VAL	56	0.510
CA	ARG	157	CA	ARG	57	0.405
CA	GLN	158	CA	GLN	58	0.139
CA	TYR	159	CA	TYR	59	0.361
CA	ASP	160	CA	ASP	60	0.252
CA	GLN	161	CA	GLN	61	0.414
CA	ILE	162	CA	ILE	62	0.337
CA	LEU	163	CA	LEU	63	0.202
CA	ILE	164	CA	ILE	64	0.359
CA	GLU	165	CA	GLU	65	0.463
CA	ILE	166	CA	ILE	66	0.347
CA	CYS	167	CA	CYS	67	0.256
CA	GLY	168	CA	GLY	68	0.471
CA	HIS	169	CA	HIS	69	0.658
CA	LYS	170	CA	LYS	70	0.489
CA	ALA	171	CA	ALA	71	0.445
CA	ILE	172	CA	ILE	72	0.396
CA	GLY	173	CA	GLY	73	0.523
CA	THR	174	CA	THR	74	0.130
CA	VAL	175	CA	VAL	75	0.156
CA	LEU	176	CA	LEU	76	0.077
CA	VAL	177	CA	VAL	77	0.129
CA	GLY	178	CA	GLY	78	0.276
CA	PRO	179	CA	PRO	79	0.272
CA	THR	180	CA	THR	80	0.580
CA	PRO	181	CA	PRO	81	0.436
CA	VAL	182	CA	VAL	82	0.328
CA	ASN	183	CA	ASN	83	0.180
CA	ILE	184	CA	ILE	84	0.151
CA	ILE	185	CA	ILE	85	0.104
CA	GLY	186	CA	GLY	86	0.059
CA	ARG	187	CA	ARG	87	0.058
CA	ASN	188	CA	ASN	88	0.183
CA	LEU	189	CA	LEU	89	0.164
CA	LEU	190	CA	LEU	90	0.051
CA	THR	191	CA	THR	91	0.216
CA	GLN	192	CA	GLN	92	0.162
CA	ILE	193	CA	ILE	93	0.158
CA	GLY	194	CA	GLY	94	0.047
CA	CYS	195	CA	CYS	95	0.050
CA	THR	196	CA	THR	96	0.200
CA	LEU	197	CA	LEU	97	0.165

Molecule 1		Molecule 2		distance [Å]
CA	ASN 198	CA	ASN 98	0.074

The distances between the polar atoms of the inhibitors **1** (Figure 1) and **2** to polar atoms of the protein, that is, hydrogen-bond donors and acceptors, were computed and are shown in Table 7.

Table 7

Distances between polar atoms of inhibitors and polar atoms of the proteins

5

	Wt: 1 complex	Wt: 2 complex
O2-Wat301	2.92	3.02
N1-027	3.36	3.58
O6-N30	3.30	3.50
O6-N29	3.19	3.51
O7-N29	2.84	-
O7-OD1 29	3.42	-
O7-O1	3.31	-
O3-OD 25 (out) A	2.5 0	2.80
O3-OD 25 (in) A	2.65	2.66
O3-OD 25 (out) B	3.27	3.07
O3-OD 25 (in) B	2.80	2.68
O5-Wat301	2.70	2.77
O8-N 30	3.16	-
N3-N 30		3.17

	Wt: 1 complex	Wt: 2 complex
N3-OD2 30		3.15

Inhibitors 1 (Figure 1) and 2 (Amprenavir) have similar structural elements, in particular their core, i.e. groups at the P1-P1' positions. However, 2 has a THF group while 1 has a bis-THF group at the P2' position. The P2 groups are identical except for the substitution of an ether oxygen atom in 1 as compared to an amine nitrogen atom at the same position in 2. Table 7 shows that 1 forms more polar interactions with the atoms of the protein that were previously identified as belonging to the structurally conserved substructure than does compound 2. For example, the O7 oxygen atom in compound 1, that forms a polar interaction with N29 nitrogen of the protease, has no counterpart in compound 2. Instead, the O6 oxygen atom of 2 forms longer (and presumably weaker) hydrogen bonds with both N30 (3.50 Å) and N29 (3.51 Å). In contrast, the O6 oxygen of compound 1 forms a shorter (and presumably stronger) hydrogen bond with N29 (3.19 Å). Additionally, as can be seen in Table 7, where both compounds 1 and 2 form interactions with polar atoms in the structurally conserved substructure of HIV protease, the distances between interacting atoms are consistently shorter for compound 1, indicative of presumably stronger binding interactions.

Example 4

Examples 2 and 3 were used to identify a three dimensionally-conserved substructure of HIV protease that is involved in the binding of HIV protease inhibitors and, in particular, to identify polar atoms of these substructural elements that are involved in forming interactions with polar atoms of HIV protease inhibitors. The following two examples demonstrate that a protease

inhibitor that contains polar atoms that can make favorable interactions with the polar atoms of the substructure may exhibit resistance-repellent properties.

Compounds 1 and 3 both contain a Bis-THF group at the P2 position that contains two polar atoms, in particular, hydrogen bond acceptor oxygen atoms, that can form hydrogen bonds with the two hydrogen atoms attached to the backbone amide nitrogen atoms on the protein at residues 29 and 30. All three compounds differ in the P2' substituent. Compounds 1 and 3 both are unaffected by the two active site mutations, V82F and I84V, and K_i values for wild type and mutant enzymes are similar for both compounds. In contrast, compound 2, which contains only a single hydrogen bond acceptor atom in the P2 substituent, is dramatically affected by the active site mutations, which demonstrate high level resistance to 2.

The antiviral activity of compounds 1 and 3 against HIV derived from patient isolates that contain multiple mutations are equivalent to their activity against wild type HIV strains. In contrast, compound 2 is much less effective against the same mutant viruses. None of the patients from whom virus was isolated had ever been exposed to any of the compounds tested herein. Nonetheless, compound 2 exhibited cross resistance to these virus strains that is typically seen with all clinically useful HIV protease inhibitors – 4 (Saquinavir), 5 (Ritonavir), 6 (Indinavir) and 7 (Nelfinavir). Compounds 2, 4, 5, 6, and 7 have very different chemical structures, but nonetheless behave as a single class with respect to their antiviral behavior against wild type and multidrug resistant HIV strains. All compounds are dramatically less potent against the multidrug resistant strains of HIV.

In sharp contrast, compounds 1 and 3, which closely resemble each other as well as compound 2, exhibit resistance-repellent behavior in that they are equally effective against wild type and mutant HIV strains that exhibit high

level multidrug resistance towards compounds 2, 4, 5, 6, and 7. The resistance-repellent activity of compound 1 was completely unexpected and contrasts with the common and typical loss of antiviral potency experienced with compounds like 2, 4, 5, 6, 7, and indeed most other HIV protease inhibitors represented as similar or different structures that have been reported.

The development and application of the 3D motif method described above successfully revealed the presence of a unique, three dimensionally-conserved substructure of HIV protease that is useful in the design of resistance-repellent inhibitors. Based on this method, compound 3 was predicted, on the basis of comparative molecular modeling using the coordinates of the complexes of compound 1 with wild type and V82F/I84V mutant HIV proteases, to be able to make the same key polar interaction as compound 1 and thereby to exhibit resistance-repellent properties. Based on these data, it is feasible to design protease inhibitors that are predicted to have resistance-repellent properties, and are predicted to be useful for the treatment of both wild type (first line therapy) and drug resistant (salvage therapy) HIV infections.

Any reference to any of the instant compounds also includes a reference to a pharmaceutically acceptable salts thereof.

Any reference to any of the instant compounds also includes a reference to a stereoisomer thereof.

Other substitutions, modifications, changes and omissions may be made in the design, operating conditions and arrangement of the preferred embodiments without departing from the spirit of the invention as expressed in the appended claims.

Additional advantages, features and modifications will readily occur to those skilled in the art. Therefore, the invention in its broader aspects is not limited

to the specific details, and representative devices, shown and described herein. Accordingly, various modifications may be made without departing from the spirit or scope of the general inventive concept as defined by the appended claims and their equivalents.

- 5 All of the references cited herein, including patents, patent applications, and publications, are hereby incorporated in their entireties by reference.

The claims below are not restricted to the particular embodiments described above.